G 3 1 1921
OF MICH.

Vol. 192 AUGUST, 1921 No. 2

1826

Journal of The Franklin Institute

1921

EDITED BY R. B. OWENS, D.S.O., D.Sc., F.R.S.C.

Associate Editors:

BRIG. GEN. JAMES ALLEN
JOSEPH S. AMES, PH.D.
WILDER D. BANCROFT, PH.D.
COL. JOHN J. CARTY, S.D.
ALLERTON S. CUSHMAN, PH.D.
ARTHUR L. DAY, SC.D.
COL. A. S. EVE, F.R.S.
W. J. HUMPHREYS, PH.D.
HARRY F. KELLER, PH.D.
A. E. KENNELLY, SC.D.
GAETANO LANZA, C.E.
RALPH MODJESKI, D.ENG.
L. A. OSBORNE, M.E.
ALBERT SAUVEUR, B.S.
MAJ. GEN. GEO. O. SQUIER, PH.D.
C. P. STEINMETZ, PH.D
S. W. STRATTON, SC.D.
CHIEF CON. D. W. TAYLOR, U. S. N.
R. S. WOODWARD, PH.D.
A. F. ZAHM, PH.D.

Committee on Publications:

GEORGE D. ROSENGARTEN, CHAIRMAN
G. H. CLAMER GEORGE A. HOADLEY W. C. L. EGLIN E. H. SANBORN

CONTENTS

The Magnetic Electron 145
ARTHUR H. COMPTON

Thermal, Electrical and Magnetic Properties of Alloys 157
ALPHEUS W. SMITH

Internal Combustion Engines in Marine Service 203
CHARLES EDWARD LUCKE

The Bifilar Windbalance 233
A. F. ZAHM

The Lukens Odometer 239
HENRY R. TOWNE AND COLEMAN SELLERS, JR.

Notes from the Research Laboratory Eastman Kodak Company 245

Notes from the U. S. Bureau of Chemistry 247

Notes from the U. S. Bureau of Mines 249

The Franklin Institute Notes 253

Book Notices 269

Publications Received 271

Current Topics 156, 238, 246, 252, 272

Published Monthly by

THE FRANKLIN INSTITUTE OF THE STATE OF PENNSYLVANIA, PHILADELPHIA

SIX DOLLARS PER YEAR (Foreign Postage Additional.) SINGLE NUMBERS, SIXTY CENTS

Entered at the Post Office at Philadelphia, Pa., as second-class matter.

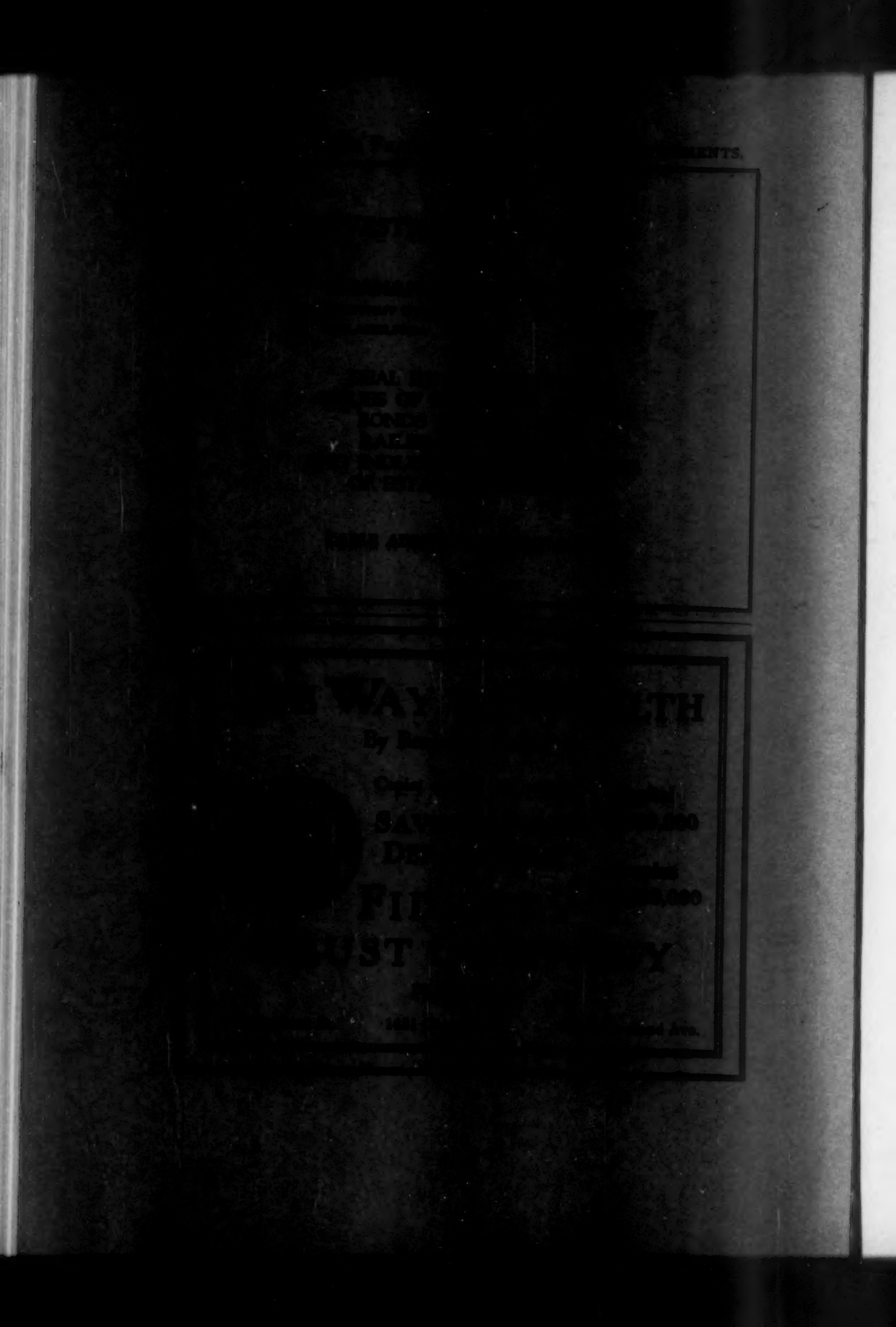
Copyright, 1921, by THE FRANKLIN INSTITUTE

Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized on July 3, 1919.

FOREIGN AGENTS

B. F. STEVENS & BROWN
4 Trafalgar Square
London, W. C. 2

GAUTHIER-VILLARS & CIE.
Quai des Grands-Augustins
Paris (6e)



Journal
of
The Franklin Institute
Devoted to Science and the Mechanic Arts

Vol. 192 AUGUST, 1921 No. 2

THE MAGNETIC ELECTRON.*

BY

ARTHUR H. COMPTON, Ph. D.,

Washington University, St. Louis.

THE evidence brought forward by the speakers who have preceded me has shown that many magnetic phenomena find a satisfactory explanation on the hypothesis that matter contains a large number of minute elementary magnets. The theories of para- and ferro-magnetism as developed by Langevin, Weiss and others, though based upon the hypothesis of such ultimate magnetic particles, make no assumptions concerning their nature. The explanation of diamagnetism, on the other hand, is based upon the view that this effect owes its origin to the circulation of electricity in resistanceless paths. The success of these theories in explaining the principal characteristics of magnetism gives us confidence in the real existence of these magnetic particles. Let us see, therefore, if it is possible to identify these elementary magnets with any of the fundamental divisions of matter.

The original investigations of ferromagnetism which led to the hypothesis of an elementary magnetic particle credited molecules with the properties of small permanent magnets. This view finds some support in the profound effect of heating, mechanical jarring, etc., on the ease of magnetization of iron. The dependence of magnetic permeability upon the chemical condition of a substance suggests the same view. But perhaps the strongest

* Based on a paper read before Section B of the American Association for the Advancement of Science, December 27, 1920.

[NOTE.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.]

COPYRIGHT, 1921, by THE FRANKLIN INSTITUTE.

argument that has been brought forward in support of the idea of molecular magnets has been the discovery of the Heusler alloys, in which by melting together elements which are only slightly magnetic an alloy with ferromagnetic properties is produced. It is, however, difficult to imagine what mechanism could reasonably give to a group of atoms, such as the chemical molecule, the properties of a single magnetic particle. Moreover, if on magnetization such a group of atoms should actually turn around within a crystal, as the elementary magnets are supposed to do, the resulting change in the positions of the atoms composing the molecule should produce a change in the crystal form; since, as we know, the form of the crystal is dependent upon the arrangement of its component atoms. It is, however, a matter of common observation that a magnetic field effects no such change in the form of a magnetic crystal.

Perhaps the most natural, and certainly the most generally accepted view of the nature of the elementary magnet, is that the revolution of electrons in orbits within the atom give to the atom as a whole the properties of a tiny permanent magnet. Support of this view is found in the quantitative explanation which it affords of the Zeeman effect. It seems but a step from the explanation of this effect to Langevin's explanation of diamagnetism as another result of the induced electronic currents within the atom. On Langevin's view the electronic orbits act as resistanceless circuits in which an external magnetic field induces changes of current. By Lenz's law these induced currents will always be in the direction to give the electronic orbit a magnetic polarity opposite to the applied field, thus accounting for the atom's diamagnetic properties. This theory offers a satisfactory qualitative explanation of diamagnetism, and accounts for the fact that diamagnetism is independent of temperature. But quantitatively it is inadequate. For, in order to explain the magnitude of the observed diamagnetic susceptibility on this view, one must suppose either that the atom possesses a number of electrons equal to several times its atomic number, or the distance between the electrons in the atom must be several times as great as is estimated by more direct methods. Moreover, the experiments of Barnett [1] and J. Q. Stewart [2] show that the ratio of charge to mass of the

[1] S. J. Barnett, *Phys. Rev.*, **6**, 240 (1915).
[2] J. Q. Stewart, *Phys. Rev.*, **11**, 100 (1918).

elementary magnet, though of the same order of magnitude, is appreciably greater than one would expect if the magnetic moment is due solely to electrons revolving in orbits. But perhaps a more serious difficulty with the usual electron theory of diamagnetism is that the induced change in magnetic moment of the electronic orbit involves also a change in its angular momentum. It is obvious, according to the classical electrical theory, that any electron revolving in an orbit will soon radiate its energy. Any angular momentum induced by an applied magnetic field will, on this theory, therefore, rapidly disappear so that diamagnetism should be merely a transient effect. Let us then assume with Bohr that if each electron has some definite angular momentum such as $h/2\pi$, no radiation occurs. On this view the electrons in the normal atom will all possess the requisite angular momentum, and when an external magnetic field is applied the induced change in angular momentum will put the electrons in an unstable condition. On this view also, therefore, the additional rotational energy induced by an applied magnetic field will not be permanent, but will soon be dissipated. In fact, the theory of atomic structure has yet to be proposed according to which diamagnetism, accounted for by the induced magnetic moment of electrons revolving in orbits, can be more than a transient phenomenon.

Besides the molecule and the atom we have the other two fundamental divisions of matter, the atomic nucleus and the electron. The sign of the Richardson-Barnett effect indicates that it is negative electricity which is chiefly responsible for magnetic effects, which makes the view that the positive nucleus is the elementary magnet difficult to defend. On the other hand, many of the magnetic properties of matter receive a satisfactory explanation on Parson's hypothesis,[3] that the electron is a continuous ring of negative electricity spinning rapidly about an axis perpendicular to its plane, and therefore possessing a magnetic moment as well as an electric charge. Thus, for example, the fact that such a ring can rotate without radiating enables this hypothesis to account for diamagnetism as a permanent instead of a transient effect. While retaining Parson's view of a magnetic electron of comparatively large size, we may suppose with Nicholson that instead of being a ring of electricity, the electron has a more nearly isotropic form with a strong concentration of electric charge near the centre

[3] A. L. Parson, Smithsonian Misc. Collections, 1915.

and a diminution of electric density as the radius increases. It is natural to suppose that the mass of such an electron is concentrated principally near its centre and that the ratio of the charge to the mass of its external portions will be greater than that for the electron as whole. While the explanation of the inertia of such a charge of electricity is perhaps not obvious, it is at least consistent with our usual conceptions and it has the advantage of offering an explanation for the large value of e/m observed in Barnett and Stewart's experiments. It also makes possible an explanation of the relatively large induced currents required to account for diamagnetism without introducing the assumption of a prohibitively large radius for the electric charge.

A series of experiments has recently been performed, designed to determine which of these fundamental divisions of matter is identical with the elementary magnet in ferromagnetic substances. The first of these, due to K. T. Compton and E. A. Trousdale,[4] had for its object the detection of any displacement of the atoms of a substance on magnetization. If the elementary magnet consists of a group of atoms such as the chemical molecule, the rotation of this elementary magnet into alignment with an applied external field will cause a displacement of the individual atoms. It is known, however, that the position of the spots on a Laue photograph depends upon the arrangement of the atoms within the crystal employed. If then, such a photograph is taken with a magnetic crystal, the character of the diffraction pattern should change when the direction of magnetization of the crystal is altered. In these experiments, however, no effect of this character was found. The obvious conclusion is that the ultimate magnetic particle does not consist of any group of atoms such as the chemical molecule.

The second of these experiments, performed by Mr. Rognley and myself,[5] was based upon the fact that the intensity of reflection of X-rays from the surface of a crystal depends not only upon the arrangement of the atoms within the crystal, but also upon the distribution of the electrons within the atoms. Let us suppose that the atom acts as a tiny magnet due to the orbital motion of its component electrons. Magnetization of the crystal will orient these atomic magnets and in so doing will change the planes of

[4] K. T. Compton and E. A. Trousdale, *Phys. Rev.*, **5**, 315 (1915).
[5] A. H. Compton and O. Rognley, *Phys. Rev.*, **16**, 464 (1920).

revolution of the electrons. This change in the electronic distribution should, therefore, affect the intensity of reflection of a beam of X-rays from the crystal's surface. An attempt was made to detect such a change in the intensity of X-ray reflection from a crystal of magnetite when strongly magnetized. Apparatus sufficiently sensitive to detect a change in intensity of less than one per cent. was employed, but magnetization of the crystal failed to produce any measurable effect. The following table shows in the first column the order of the X-ray spectrum line which was being studied; in the second column

TABLE I.

Order	E_1/E_u	E_2/E_u	E_3/E_u
1	1.05	1.000	1.004
2	1.27	0.96	1.03
3	1.48	0.86	1.09
4	1.70	0.51	1.09

the calculated ratio of intensity from the magnetized to that from the unmagnetized crystal, supposing the atom to have the Rutherford form; and the third and fourth columns represent the similar ratios as estimated from a cubic form of atom. In the third column it is supposed that the magnetic axis is perpendicular to a cube face, and in the fourth column that the magnetic axis is along the cube diagonal. According to experiment the value of these ratios was always unity, at least within one per cent. It is clear that none of the types of atoms considered could be oriented by a magnetic field without producing a noticeable effect. In fact, it is difficult to imagine any form of magnetic atom which would be so nearly isotropic that it would have given no effect in our experiment. It is, therefore, difficult to avoid the conclusion that the elementary magnet is not the atom as a whole.

Since neither the molecule nor the atom gives a satisfactory explanation of these experiments, the view suggests itself that it is something within the atom, presumably the electron, which is the ultimate magnetic particle. Let us see then if we can find any positive evidence for the existence of an electron with a magnetic moment.

On the basis of the classical dynamics we should expect the electron, whatever its form, to possess thermal energy of rotational motion, equal on the average to that of a molecule or atom

at the same temperature. On Planck's more recent quantum hypothesis, however, which is perhaps the more reasonable view, at the absolute zero of temperature each particle of matter—including the electron—should retain an average amount of energy ½hν for each degree of freedom for motion. For a rotating system this corresponds to an angular momentum of $h/2\pi$. Thus whatever view we adopt, the thermal motions of the electron will give to it an appreciable magnetic moment. For a particle of the small moment of inertia of the electron, the frequency of rotation corresponding to an angular momentum $h/2\pi$ will be exceedingly high, and the corresponding energy ½hν will be large compared with the additional energy which it may acquire due to an increase in temperature. Thus the angular momentum, and hence also the magnetic moment of the electron, will be nearly the same at different temperatures—a property characteristic of the elementary magnets. It is interesting to notice, also, that the magnitude of the magnetic moment of an electron spinning with an angular momentum $h/2\pi$ is of the proper order to account for ferromagnetic properties, being about one-third the magnetic moment of the iron atom.

If an electron with such an angular momentum is to have a peripheral velocity which does not approach that of light, it is necessary that the radius of gyration of the electron shall be greater than 10^{-11} cm. While such an electron is much larger than the spherical electron of Lorentz, recent experiments on the scattering of X-rays and gamma rays indicate the electron's diameter may be even greater than the minimum value thus required to explain magnetic properties. Experiment shows that the scattering of very high frequency radiation is considerably less than theory demands if the electron is supposed to have negligible dimensions. In the case of hard gamma rays, indeed, I have found the scattering at certain angles to fall below 1/1000, the intensity predicted on the usual theory.[6] The only adequate explanation of these experiments seems to be that interference occurs between the rays scattered from the different parts of the same electron. Such an explanation clearly implies that the diameter of the electron is comparable with the wave-length of the radiation employed, which means that the effective radius of the electron is of the order of 10^{-10} cm. Considerations of the size of the electron, therefore,

[6] A. H. Compton, *Phil. Mag.* (in printer's hands).

support rather than oppose the view that the electron may have an appreciable magnetic moment.

Further evidence that the electron possesses properties other than those of an electric charge of negligible dimensions is afforded by a study of the white X-radiation emitted at the target of an X-ray tube. It was noticed by Kaye that the X-rays emitted in the direction of the cathode ray beam are harder and more intense than those traveling in the opposite direction. The difference in both hardness and intensity of the radiation at different angles is in good accord with the view proposed by D. L. Webster that the particles emitting the radiation are moving in the direction of the cathode-ray beam, giving rise to a Doppler effect. Indeed, it is very difficult to give any other explanation of the difference in wave-length of the radiation in different directions. But, on this view, in order to account for the difference in hardness observed in the case of gamma rays, the radiating particles must have a velocity of about one-half the speed of light. Since the highest known speeds at which atoms travel is only about one-tenth the velocity of light, as observed in the case of alpha particles, the swiftly moving radiators giving rise to this high-frequency X-radiation must therefore be free electrons. If this view is correct, it follows, as Webster has pointed out, that the electron must be a system capable of emitting radiation, and is therefore, not a mere charge of electricity of negligible dimensions. On the present view we may well suppose that the electron is spinning like a gyroscope and on traversing matter is set into mutational oscillations, resulting in the observed radiation.

Strong evidence that the electron possesses a magnetic moment is afforded by H. S. Allen's recent explanation of the rotation of the plane of polarization by optically active substances.[7] You will remember in Drude's classical work it is found that optical rotation may be explained if the electrons, when made to oscillate by a passing electric wave, do not move exactly in the plane of the electric vector. He supposes rather that there is a component of motion at right angles to the electric vector and finds that such a motion will account for the observed rotation. Allen shows that the motion perpendicular to the electric vector which Drude assumes is a natural consequence of the view that the electron is magnetic and has an appreciable diameter. It would take us too

[7] H. S. Allen, *Phil. Mag.*, **40**, 426 (1920).

far afield to discuss the details of this work, but the significance of the result is obvious, since it has heretofore been difficult to give a reasonable account of the type of motion postulated by Drude.

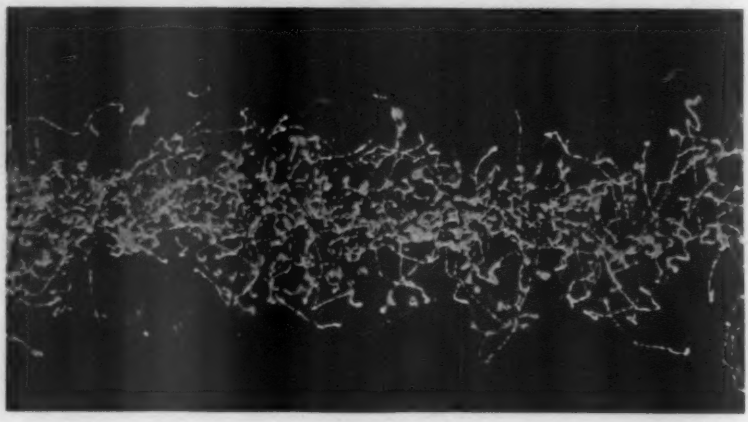
Finally, I wish to discuss a phenomenon, first noticed by C. T. R. Wilson and brought to my attention by Mr. Shimizu, which, if its obvious explanation is correct, gives direct evidence that free electrons possess magnetic polarity. Suppose that a magnetic electron is placed in a homogeneous paramagnetic medium. Every part of the medium will be slightly magnetized in the direction of the lines of force, and the magnetic field at the electron due to the magnetic moment of each portion of the medium will have a positive component in the direction of the electron's magnetic axis. Thus the magnetization induced in the surrounding medium will give rise to a magnetic force at the electron in the direction of its own magnetic axis. The case is exactly analogous to placing a bar magnet in a field of iron filings. The iron filings will be magnetized by induction in the direction of the lines of force and if the bar magnet is removed, there still exists a magnetic field where the magnet was because of the magnetization of the surrounding iron filings. If now the electron is in motion, this induced magnetic field will produce the same effect as would an externally applied field of the same intensity. That is, the force due to the magnetic field from the surrounding medium acting on the moving electric charge will make it follow a curved instead of a straight path.

If, because of its gyroscopic action, the axis of the electron does not change its direction, the induced magnetic field will always be in the same direction, and the electron will describe a helical orbit. In any actual medium, composed of discreet particles and therefore not homogeneous on an electronic scale, this spiral motion will be superposed upon an irregular motion due to collisions, and the axis of the electron will not remain fixed in direction. Thus any spiral motion that may appear should be rather broken. A rough calculation, assuming an electron to be projected into air with a speed corresponding to a drop through 10,000 volts, which is about that of the secondary cathode rays produced by ordinary X-rays, and having a magnetic moment corresponding to the angular momentum $h/2\pi$, indicates that the induced magnetic field at the electron should be of the order of 3000 gauss, if the permeability of the medium is that of ordinary air. This field

is strong enough to produce a very decided curvature in the electron's path, so in spite of the irregularities in the electron's motion we might hope to observe experimentally the predicted helical tracks.

Below are a few of C. T. R. Wilson's photographs of the tracks of secondary cathode rays and beta particles. In the first figure are seen the tracks of the cathode rays ejected by a comparatively intense beam of X-rays. Let me call your attention particularly to the two tracks marked by arrows. You see here paths in the form of almost perfect helices. Most of the tracks are too

FIG. 1.



irregular and too confused with each other to trace so perfect a spiral form; but you will notice that in almost every case, the track terminates in a close spiral. The tracks can be examined more satisfactorily if we use a photograph showing a smaller number. In the next figure I have called attention particularly to three tracks. It is unfortunate that one cannot show these paths on the screen in three dimensions. Mr. Wilson showed me some remarkable stereoscopic photographs, as yet unpublished, which he obtained of X-rays passing through air. In one of these, showing altogether about 66 complete tracks, all but about 14 seemed to be of a spiral form. Of these fourteen 12 were too irregular to detect with certainty any spiral tendency that might exist, and the remaining two were for the most part straight. But to me

there seemed no doubt, nor did there to others who examined them carefully, but that there was a real tendency to spiral motion in the tracks of these secondary cathode particles.

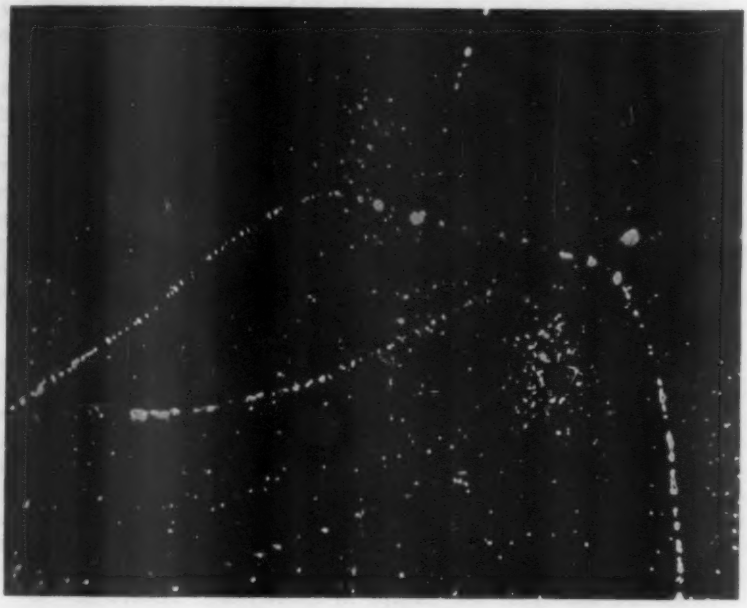
The beta rays from radium show the same consistent curvature. Notice particularly the path shown in Fig. 3 with its almost uniform curvature. If one would calculate the probability of such a curvature on the basis of chance collisions, each as likely to deflect the particle in one direction as in another, this type of path would be declared impossible.

FIG. 2.

Examining again the tracks of the secondary cathode rays, let us see how their form compares with that to be expected for gyroscopic magnetic electrons. In the first place we find that the tracks exhibit a helical curvature of the kind we should anticipate. In the second place the axis of the helix is different for each beta particle, which we should anticipate since each beta particle induces its own magnetic field and the direction of the field is coincident with its own axis. And, finally, we notice changes in the direction of curvature such as might well result from sudden precessions of the electron's gyroscopic axis. If the obvious explanation of these spiral tracks is the correct one, we have here positive evidence for our hypothesis that the electron acts as a tiny magnet as well as an electric charge.

Let us then review the different lines of evidence that have given us information concerning the nature of the elementary magnet. In the first place, the Richardson-Barnett effect shows that magnetism is due chiefly to the circulation of negative electricity whose ratio of charge to mass is not greatly different from that of the electron. In the second place, experiments on the diffraction

FIG. 3.



of X-rays by magnetic crystals indicate that the elementary magnet is not any group of atoms, such as the chemical molecule, nor even the atom itself; but lead rather to the view that it is the electron rotating about its own axis which is responsible for the ferromagnetism. And finally, positive evidence in favor of the hypothesis of some form of magnetic electron is supplied by a consideration of the curvature of the tracks of beta rays through air. May I then conclude that the electron itself, spinning like a tiny gyroscope, is probably the ultimate magnetic particle.

Substitution of Turbidity for Nephelometry. W. DENIS, of Tulane University (*Jour. Biol. Chem.*, 1921, xlvii, 27–31), states that determinations of turbidity, made by means of colorimeter, may advantageously be substituted for nephelometric determinations in a number of analytical procedures. Turbidimetric readings give quantitative results with large variations in concentration between the standard and the unknown. Therefore turbidimetric determinations may be made without the preparation of the large number of standards which are required in nephelometric work. J. S. H.

Oil of Oats. ERNEST PAUL (*Analyst*, 1921, xlvi, 238–239) has made a study of the oil obtained from oats by extraction with hot petroleum ether. The oats were dried at a temperature of 36°, and still contained 4 per cent. of moisture. They were ground, then extracted with the solvent by percolation under pressure until practically fat-free. The yield of oil was 4.32 per cent. of the dry sample. The oil contained approximately 1 per cent. of lecithin. The chemical constants of the oil resembled those of maize or corn oil. Its drying properties were determined by means of films on ground glass plates. At ordinary temperatures, gumming only commenced in two months, while a hard varnish was produced in two to three days at a temperature of 99° C. Approximately one-third of the oil was free fatty acids. J. S. H.

International Normal Weight for the Saccharimeter.—The International Commission for Uniform Methods of Sugar Analysis in 1900 adopted 26 grams as the normal weight to be used in the direct determination of the per cent. of sucrose or cane sugar by means of the polarimeter. The French generally use a normal weight of 16.29 grams. Recently the suggestion has been made to adopt a sugar scale with a normal weight of 20 grams. According to the *Analyst*, 1921, xlvi, 268, British chemists are largely in favor of retaining the present international standard normal weight, which is in almost universal use except in France and Mauritus.

J. S. H.

On a Lecture Demonstration of the Absolute Determination of Resistance. F. E. SMITH. (*Proc. Phys. Soc. of London*, vol. 33, part 3.)—The usual feeling is that any such determination as this is of a highly recondite character, yet Mr. Smith demonstrated the experiment to an audience of the London Physical Society, and allows only two or three minutes for its performance. He boldly suggests that a similar demonstration be incorporated in courses of lectures on electricity. His apparatus was based on the original British Association coil. Two coils, each of several hundred turns, were placed side by side so as to allow a magnetic needle to be suspended at the centre. They are rotated in the earth's field. Thus a current was induced in them, which deflected the needle. The exhibition of this experiment is proposed as a means of arousing interest in absolute measurements. G. F. S.

THERMAL, ELECTRICAL AND MAGNETIC PROPERTIES OF ALLOYS.*

BY

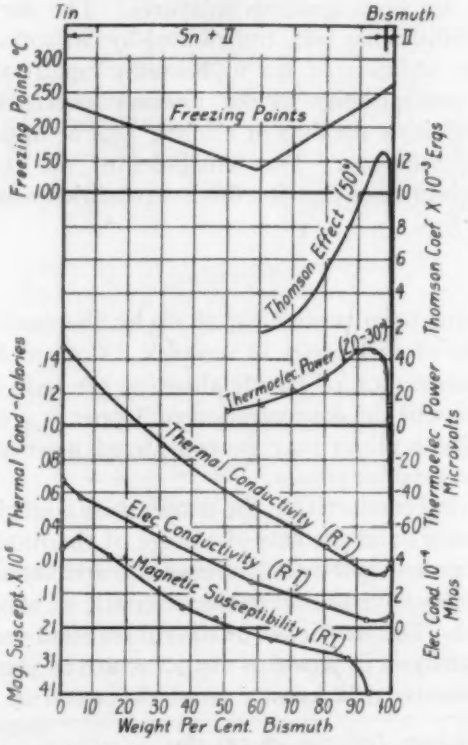
ALPHEUS W. SMITH, Ph.D.

Ohio State University.

Bismuth-Tin.

The freezing point curve (Fig. 27) from data of Stoffel [85] and Lepkowski [86] consists of two branches meeting at a eutectic. Except for small and possibly large concentrations of tin where the

FIG. 27.



metals may be soluble in each other to a limited extent, these alloys are mechanical mixtures of bismuth and tin.

---

* Concluded from page 105, vol. 192, July, 1921.

[85] Stoffel: *Zeit. anorg. Chem.*, 53, 148, 1907.

[86] Lepkowski: *Zeit. anorg. Chem.*, 59, 287, 1908.

The thermoelectric powers of these alloys have been studied by Hutchins [87] and also by Caswell.[88] The curve for the Thomson effect as determined by Laws and also by Caswell is very similar to the curve for the thermoelectric heights. Each curve shows a pronounced maximum when a small quantity of tin is present in the alloy. The curves for electrical and thermal conductivities by Schulze [89] have minima where the preceding curves have maxima. These maxima and minima occur in the region in which the alloys seem to be dilute solid solutions of tin in bismuth. The remainder of the curve for thermal conductivity as well as the curve for electrical conductivity is roughly linear, the form to be expected in alloys which are heterogeneous mixtures. The curve for magnetic susceptibilities has been contributed by Gnesotto and Binghinotto.[90] The addition of tin to bismuth rapidly decreases the diamagnetic susceptibility in the interval where the preceding curves showed either maxima or minima, that is, in the interval of possible solid solutions. The remainder of the curve suggests mechanical mixtures except for the irregularities where the alloys are nearly all tin.

Copper-Zinc.

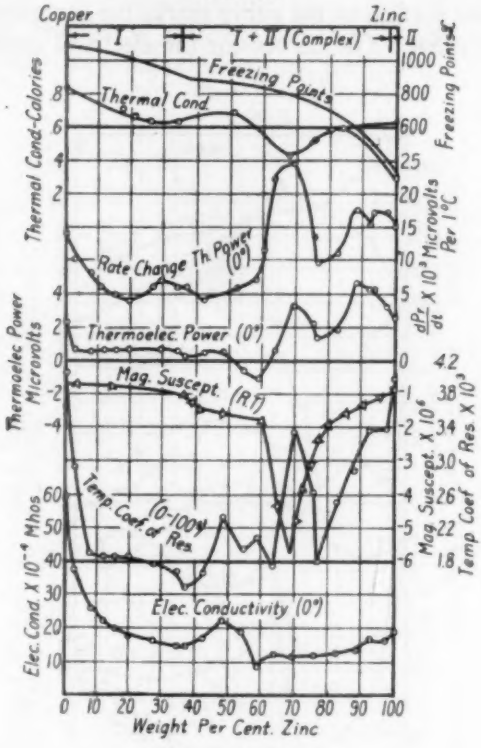
The freezing point curve (Fig. 28) is by Shepherd and others.[91] The structure of this series is complex. Copper dissolves zinc until the concentration of zinc is about 35 per cent. and zinc dissolves copper until the concentration of copper is 2 or 3 per cent. The intermediate alloys may be considered heterogeneous mixtures of two crystalline phases.

The electrical conductivity, the temperature coefficient, the thermoelectric powers and the rate of change of thermoelectric power have been measured by Norsa.[92] Between 0 and about 35 per cent. zinc these curves have the form characteristic of alloys which are solid solutions. The remainder of the curves seem too complicated to admit of analysis in terms of the structure of the alloys. The thermal conductivity is known from the work of Calvert and

[87] Hutchins: *Amer. Jour. Sci.*, **48**, 226, 1894.
[88] Caswell: *Phys. Rev., N. S.*, **12**, 226, 1918.
[89] Schulze: *Ann. d. Phys.*, **9**, 566, 1902.
[90] Gnesotto and Binghinotto: *Inst. Ven.*, 69, 1382.
[91] Guertler: *Metallographie*, i, 459.
[92] Norsa: *C. R.*, **155**, 348, 1912.

Johnson.[93] The course of this curve is somewhat irregular. The curve for the magnetic susceptibility has been plotted from data by Weber.[94] Between 0 and 35 per cent. zinc it is a straight line.

FIG. 28.



Copper-Tin.

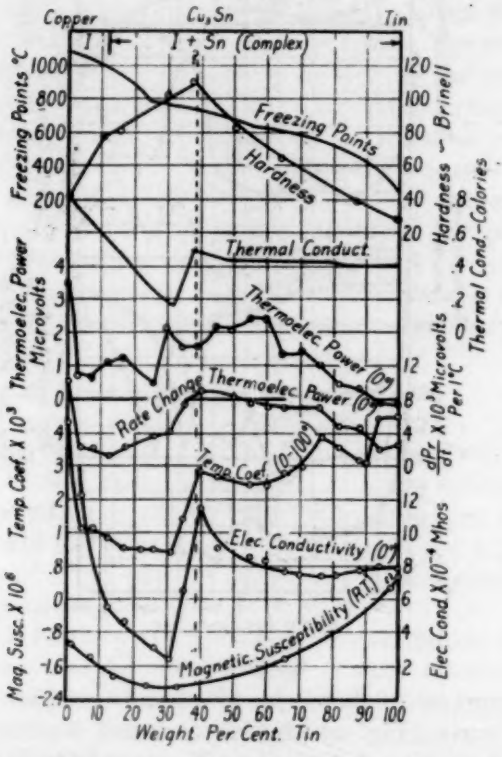
The structure of this series of alloys is complex. The freezing point curve (Fig. 29) by Heycock and Neville[95] gives evidence of one compound Cu_3Sn. Tin is soluble in copper until there is about 13 per cent. copper present. The remainder of the alloys may be considered as mechanical mixtures of two crystalline phases.

The curve for hardness by Kurnakow and Zemczuzny[96] con-

[93] Calvert and Johnson: *Phil. Mag.*, **18**, 354, 1850.
[94] Weber: *Ann. d. Phys.*, **62**, 666, 1920.
[95] Heycock and Neville: *Phil. Trans. A.*, **202**, 1, 1904.
[96] Kurnakow and Zemczuzny: *Zeit. anorg. Chem.*, **60**, 9, 1908.

sists of two straight lines and a curve of gentle slope. The two straight lines intersect where the concentration of tin is about 11 per cent. and thus mark the concentration at which tin ceases to be soluble in copper. The intersection of the second straight line with the third portion of the curve marks the concentration for the compound Cu_3Sn. The curves for the electrical conductivity, the

FIG. 29.

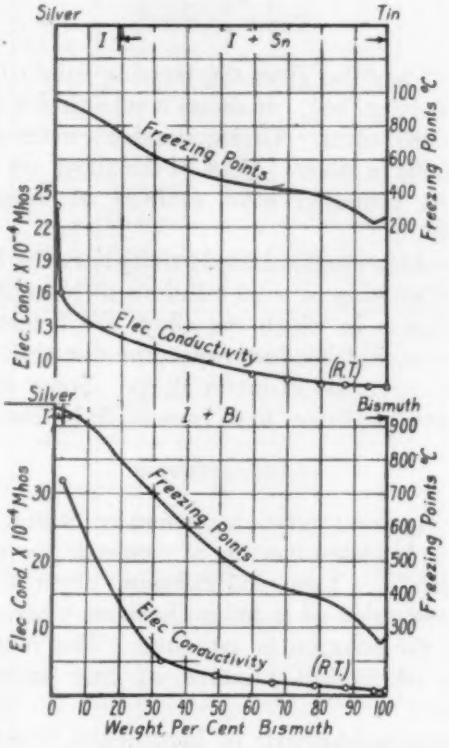


temperature coefficient, the thermoelectric power and its variation with the temperature have been plotted from the observations of Leroux.[97] Between 0 and 35 per cent. tin the curves for electrical conductivities and that for the temperature coefficients are typical of alloys which are solid solutions. Where the solution becomes saturated the direction of the curves suddenly changes. The position of the intermetallic compound is marked on these curves

[97] Leroux: *C. R.*, **155**, 35, 1912.

by cusps. The curve for thermal conductivities is very similar to the curve for electrical conductivities. Wiedemann and Franz's law must, therefore, hold approximately for these alloys. The curve for the magnetic susceptibilities by Clifford [98] does not show the compound, but this is probably due to the fact that the points on the curve near the compound are too far apart.

FIG. 30.



Silver-Tin.

The freezing point curve for silver-tin alloys (Fig. 30) by Petrenko [99] is in complete agreement with the curve obtained by Heycock and Neville. Silver is only slightly soluble in tin and tin is soluble in silver until the concentration of tin is about 18

[98] Clifford: *Phys. Rev.*, **26**, 424, 1908.

[99] Petrenko: *Zeit. anorg. Chem.*, **50**, 138, 1906; also **53**, 200, 1907.

per cent. The other alloys are, therefore, heterogeneous mixtures of two crystalline phases.

The electrical conductivity curve by Matthiessen [100] shows an initial rapid drop for alloys rich in silver. This is characteristic of alloys which are solid solutions. The remainder of the curve has the general shape of curves for a mechanical mixture of two crystalline phases.

Silver-Bismuth.

Petrenko [101] has also given the freezing point curve for silver-bismuth alloys (Fig. 30). It shows a eutectic for alloys containing 2.5 per cent. silver. Under suitable conditions bismuth is somewhat soluble in silver. Most of the alloys are heterogeneous mixtures of a saturated solid solution of bismuth in silver and of bismuth.

The form of the electrical conductivity curve by Matthiessen [102] suggests the formation of solid solutions of bismuth in silver followed by a region in which the alloys are heterogeneous mixtures. The electrical conductivity curve for this series is very similar to the curve for silver-tin alloys. Some observations on thermoelectromotive forces have been made by Battelli.[103]

Lead-Cadmium.

The freezing point curve, according to Stoffel [104] (Fig. 31), consists of two branches meeting at a eutectic for which the temperature is 249° C. Lead and cadmium form a solid solution until the concentration of cadmium is about 5 per cent., at which concentration the solution is saturated. The remainder of the alloys are a mechanical mixture of this saturated solution and cadmium.

The electrical conductivity by Matthiessen [102] is nearly a linear function of the concentration. There are no points on the curve in the region between 95 and 100 per cent. lead in which the solid solutions are now known to be formed.

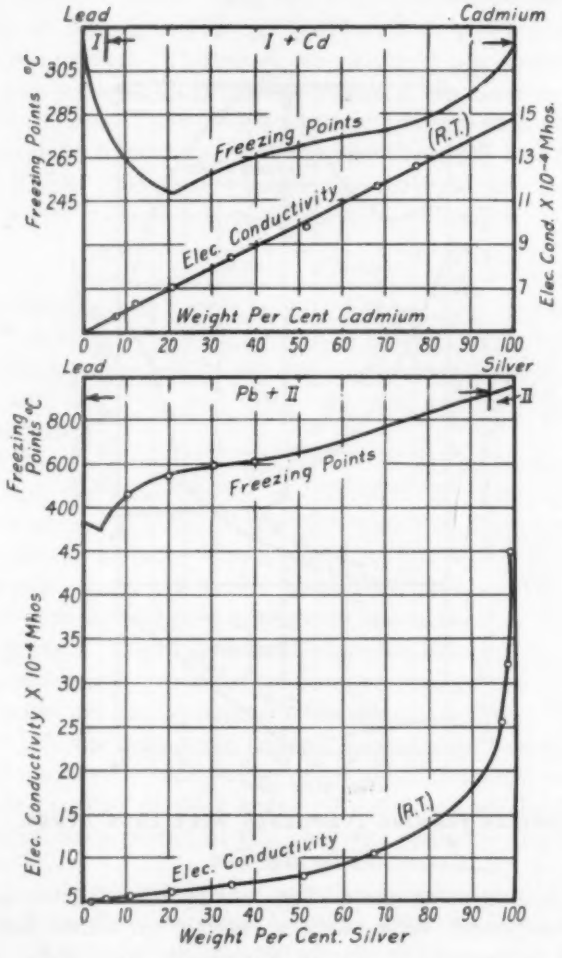
---

[100] Matthiessen: *Pogg. Ann.*, 110, 215, 1860.
[101] Petrenko: *Zeit. anorg. Chem.*, 50, 138, 1906; also 53, 200, 1907.
[102] Matthiessen: *Pogg. Ann.*, 110, 208, 1860.
[103] Battelli: *Atti. R. Inst. Ven.* (6), 5, 1148, 1886.
[104] Stoffel: *Zeit. anorg. Chem.*, 53, 152, 1907.

Lead-Silver.

The freezing point curve by Petrenko [101] (Fig. 31) shows a eutectic for which the temperature is 303.9° C. Lead is soluble in silver until the alloy contains about 5 per cent. lead. The re-

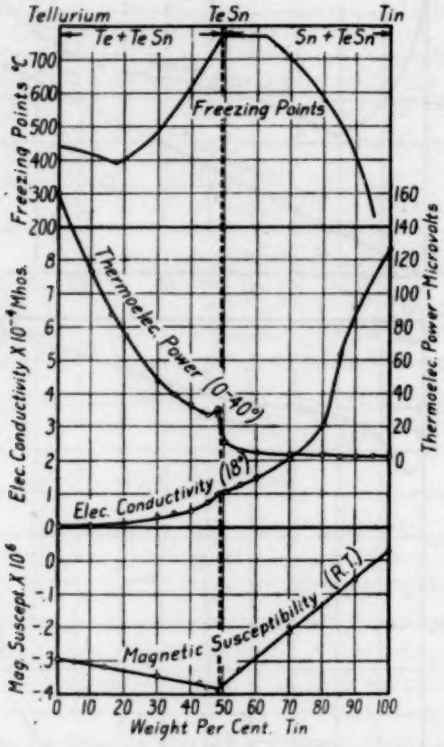
FIG. 31.



mainder of the alloys are heterogeneous mixtures of this solid solution and lead. The structure of these alloys is very similar to the structure of the lead-cadmium alloys.

The curve for electrical conductivities by Matthiessen [105] is very steep between 100 and 97 per cent. silver. This is the region in which a solid solution of lead in silver is formed. For alloys containing less than 50 per cent. silver the curve becomes nearly a straight line, which is characteristic of mechanical mixtures of two crystalline phases.

FIG. 32.



METALS FORMING COMPOUNDS WITH EACH OTHER.

Tellurium-Tin.

The freezing point curve (Fig. 32) by Fay [106] gives the intermetallic compound TeSn, with a eutectic on either side. The results of Kobayashi [107] are in agreement with those of Fay.

[105] Matthiessen: *Pogg. Ann.*, 110, 212, 1860.
[106] Fay: *Jour. Amer. Chem. Soc.*, 29, 1265, 1907.
[107] Kobayashi: *Zeit. anorg. Chem.*, 69, 1, 1911.

Alloys containing less than 48 per cent. tin are mechanical mixtures of tellurium; the compound TeSn and those containing more than 48 per cent. tin are mechanical mixtures of tin and the compound TeSn.

The thermoelectric powers and the electrical conductivities in Fig. 32 are by Haken [108] and the magnetic susceptibilities from the work of Honda and Sone.[109] The compound is indicated on each of the curves. The curve for magnetic susceptibilities consists of two straight lines which intersect at the concentration giving the compound TeSn. One of these straight lines corresponds to mixtures of tellurium and TeSn and the other to mixtures of tin and TeSn. Between 55 and 100 per cent. tin the thermoelectric power curve is a straight line of small slope.

Bismuth-Tellurium.

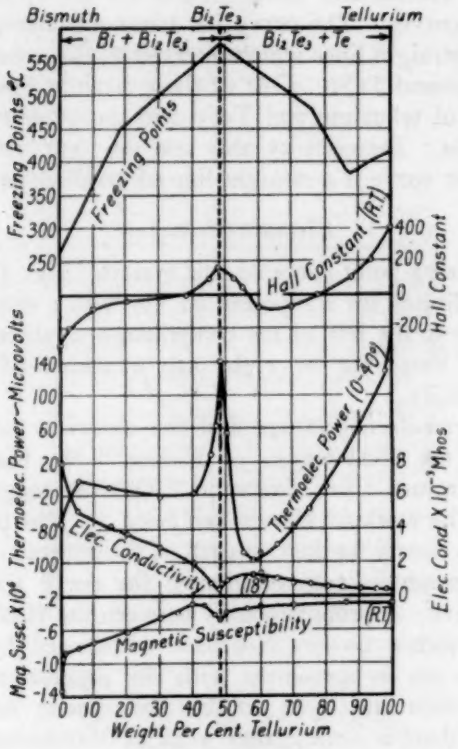
The freezing point curve of this system (Fig. 33) by Monkemeyer [110] indicates the compound Bi_2Te_3 with a eutectic on either side. Alloys to the left of the compound are mixtures of Bi and Bi_2Te_3 and those to the right are mixtures of Te and the compound Bi_2Te_3.

The thermoelectric power and the electrical conductivity are taken from the observations of Haken,[111] the Hall constant at room temperature from Trabacci [112] and the magnetic susceptibility from the work of Honda and Sone.[113] The presence of the compound is clearly marked on each of the curves. The curve for the Hall constant is very similar to the curve for the thermoelectric powers. A proportionality between the Hall constants and the thermoelectric powers has been recognized by Beattie and these curves are in agreement with the suggestion. Beside the work of Honda and Sone on the diamagnetic susceptibility of these alloys there is some earlier work by Mendenhall and Lent [114] who failed to find in their curve an indication of the compound. Honda and Sone point out that this was probably due to the fact

[108] Haken: *Ann. d. Phys.*, **32**, 291, 1910.
[109] Honda and Sone: *Sci. Repts. Imp. Univ. Tokio*, **2**, 10, 1913.
[110] Monkemeyer: *Zeit. anorg. Chem.*, **46**, 415, 1905.
[111] Haken: *Ann. d. Phys.*, **32**, 291, 1910.
[112] Trabacci: *Nuovo Cim.*, **9**, 95, 1915.
[113] Honda and Sone: *Sci. Repts. Imp. Univ. Tokio*, **2**, 12, 1913.
[114] Mendenhall and Lent: *Phys. Rev.*, **32**, 406, 1911.

that Mendenhall and Lent did not take the points in the neighborhood of the compound close enough together. Between 1 and 41 per cent. tellurium and between 60 and 100 per cent. tellurium the susceptibility curve is nearly a straight line which is characteristic of mechanical mixtures.

FIG. 33.



Bismuth-Magnesium.

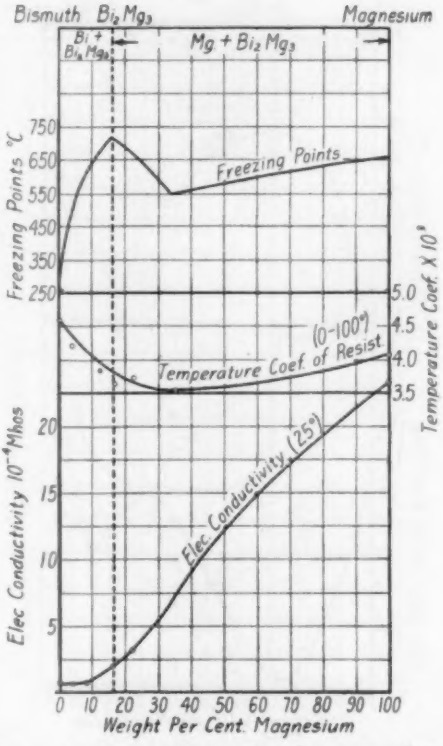
The freezing point curve (Fig. 34) by Grube [115] gives one compound Bi_2Mg_3 and one eutectic for this combination of metals. Another eutectic is probably formed between bismuth and the compound Bi_2Mg_3, but the temperature of this eutectic nearly coincides with the melting point of bismuth. Alloys to the left of the compound consist of heterogeneous mixtures of bismuth

[115] Grube: *Zeit. anorg. Chem.*, **49**, 85, 1906.

and the compound Bi_2Mg_3 and those to the right of mixtures of magnesium with the compound Bi_2Mg_3.

The electrical conductivity and the average temperature coefficient have been determined by Stepanow.[116] Neither of these curves show the presence of the compound Bi_2Mg_3. This may be due to the fact that the points in the neighborhood of this

FIG. 34.



compound were not taken sufficiently close together. The course of the curves on either side of the compound somewhat resembles straight lines, indicating that the alloys on the two sides of the compound are mechanical mixtures.

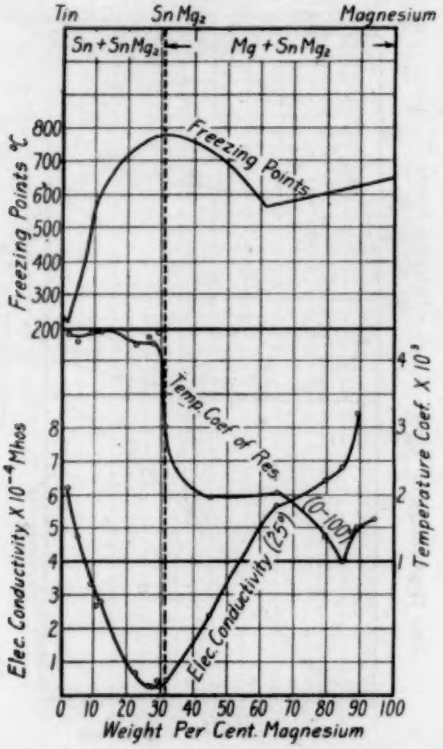
Magnesium-Tin.

The equilibrium diagram for magnesium and tin shows one

[116] Stepanow: *Zeit. anorg. Chem.*, **78**, 1, 1912.

intermetallic compound, Mg_2Sn. There is a eutectic on either side of this compound. The freezing point curve of Fig. 35 is by Grube.[117] Magnesium does not seem to be soluble in tin, but Grube finds that magnesium dissolves about 6 per cent. of tin. With the exception of alloys in this region, the alloys of this series are mechanical mixtures of two crystalline phases.

FIG. 35.

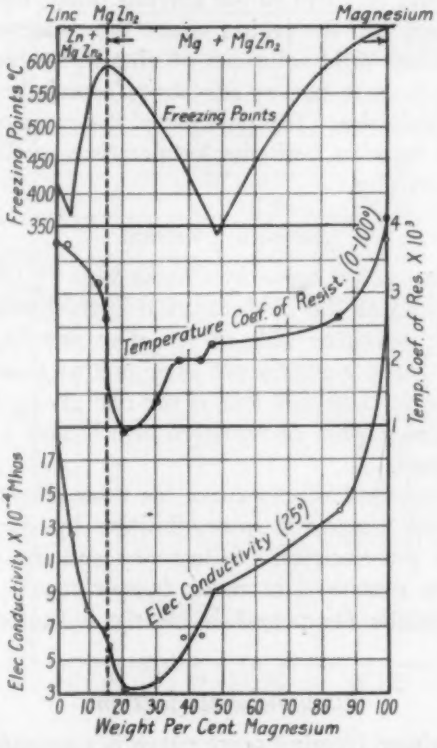


The electrical conductivities and the temperature coefficients of the resistance are known from the work of Stepanow.[118] The addition of tin to magnesium causes a rapid drop in the electrical conductivity and the temperature coefficient. The steepness of these curves for large concentrations of magnesium confirms the existence of solid solutions of magnesium and tin where the concentration of tin is small. The compound is marked by a rapid

[117] Grube: *Zeit. anorg. Chem.*, 46, 1905.

drop in the temperature coefficient and a minimum in the electrical conductivity. Between 0 and about 28 per cent. and between 40 and 65 per cent. magnesium the temperature coefficient is nearly constant. This constancy could be inferred from the fact that the alloys over these regions are mechanical mixtures, in the former case of tin and the compound $SnMg_2$ and in the latter case of the

FIG. 36.



compound $SnMg_2$ and a saturated solid solution of magnesium and tin.

Magnesium-Zinc.

These two metals, according to Grube,[118] from whose work the freezing point curve of Fig. 36 is taken, form one intermetallic compound with the formula $MgZn_2$. On either side of

[118] Grube: *Zeit. anorg. Chem.*, **49**, 80, 1906.

this compound is a eutectic and the alloys to the left of the compound may be regarded as heterogeneous mixtures of zinc and the compound $MgZn_2$ and those to the right of the compound, mixtures of magnesium and the compound $MgZn_2$. It seems possible that zinc may form dilute solid solutions with magnesium.

The electrical conductivities and the temperature coefficients of the resistance are from the observations of Stepanow.[119] These curves are similar in form to the corresponding curves for magnesium-tin alloys. In the region where the concentration of zinc is small and dilute solid solutions of zinc in magnesium may be formed both of these curves are steep, especially the curve of electrical conductivities. The position of the compound is marked by a rapid decrease in both the temperature coefficient and the electrical conductivity.

Bismuth-Thallium.

The freezing point curve by Chickashige[120] (Fig. 37) indicates a compound at the concentration corresponding to Bi_5Tl_3 with a eutectic on either side of it. The freezing point curve seems to have three maxima, but only one of them corresponds to a simple atomic ratio, and that is the one giving the compound Bi_5Tl_3. A micrographic examination also locates a compound in this neighborhood.

The electrical conductivity curve for these alloys are by Whitford[121] and the magnetic susceptibilities by Mendenhall and Lent.[122] Both the electrical conductivity and the magnetic susceptibility were measured at room temperature. The presence of the intermetallic compound is clearly indicated on both of these curves.

Aluminium-Magnesium.

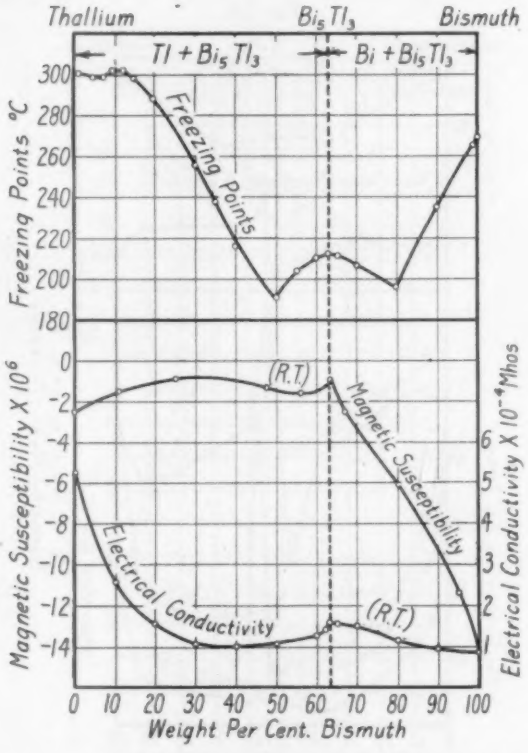
Grube[123] whose freezing point curve is reproduced in Fig. 38 finds one maximum which corresponds to either Al_2Mg_3 or Al_3Mg_4. These compounds lie so close together that it is difficult to choose between them, but Grube concludes that Al_3Mg_4 is the more prob-

[119] Stepanow: *Zeit. anorg. Chem.*, **78**, 25, 1912.
[120] Chickashige: *Zeit. anorg. Chem.*, **51**, 328, 1906.
[121] Whitford: *Phys. Rev.*, **35**, 144, 1912.
[122] Mendenhall and Lent: *Phys. Rev.*, **32**, 415, 1911.
[123] Grube: *Zeit. anorg. Chem.*, **45**, 225, 1905.

able. To the right of this compound the alloys may be considered mechanical mixtures of Mg and the compound Al_3Mg_4 and for lower concentrations of magnesium they are mechanical mixtures of aluminium and the compound Al_3Mg_4.

Besides the observations of Broniewski [124] from which the

FIG. 37.



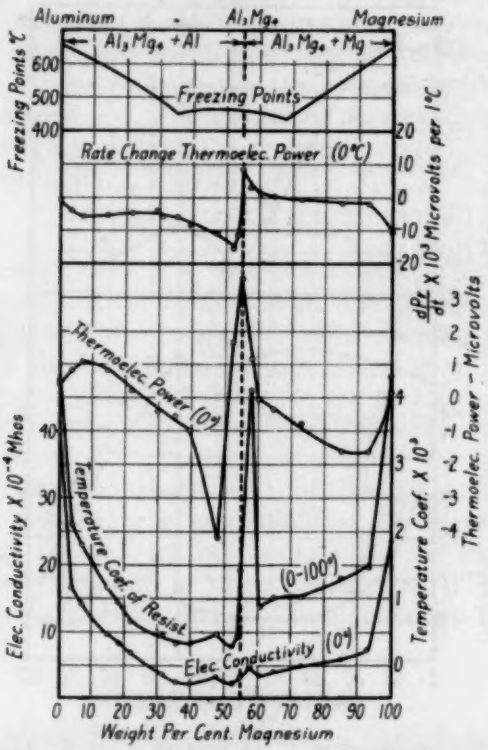
curves in Fig. 38 have been plotted there are observations by Pecheux [125] on the thermoelectromotive forces of some members of this series. According to the interpretation of Broniewski, two compounds are indicated by his curves: *viz.*, AlMg and Al_2Mg_3. Of these compounds Al_2Mg_3 is much more clearly marked than the compound AlMg.

[124] Broniewski: *Ann. de Phys. et Chem.* (8), **25**, 76, 1912.
[125] Pecheux: *C. R.*, **139**, 1202, 1904.

Copper-Arsenic.

The freezing point curve of Fig. 39 is by Friedrich.[126] From the equilibrium diagram and from a metallographic study of these alloys it is found that copper and arsenic form two compounds Cu_3As and Cu_3As_2 and that arsenic dissolves in copper up to 4 per cent.

FIG. 38.

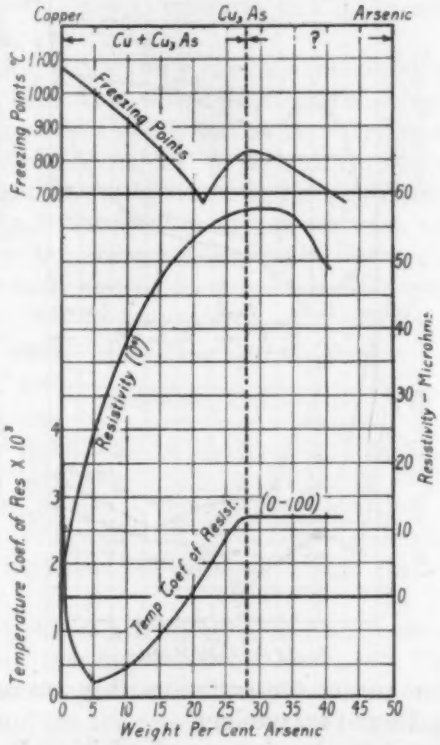


Some observations on the electrical conductivity of copper-arsenic alloys have been made by Matthiessen and Holtzmann [127] and later by Hampe.[128] Friedrich also gives some data on the electrical resistance of these alloys for low concentrations of arsenic. The specific resistance of these alloys and the tempera-

[126] Friedrich: *Metallurgie*, 5, 529, 1908.
[127] Matthiessen and Holtzmann: *Pogg. Ann.*, 110, 229, 1860.
[128] Hampe: *Chemiker, Ztg.*, 726, 1892.

ture coefficient (Fig. 39) are the values given by Puschin and Dischler.[129] The electrical resistance of copper is much increased by the addition of small quantities of arsenic, and the temperature coefficient is decreased. This occurs in the region where a solid solution of arsenic in copper is formed and is characteristic of the formation of such solutions. When the concentration of arsenic is about 28.5 per cent. the specific resistance has its maximum

FIG. 39.



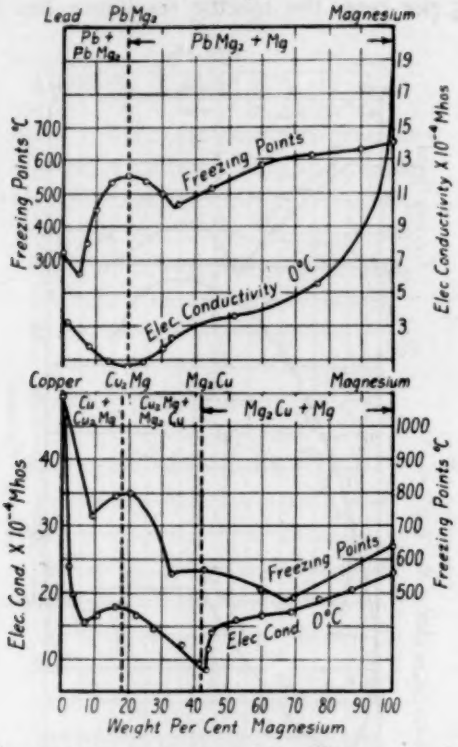
value. This maximum value comes at the concentration for the compound Cu_3As. The temperature coefficient decreases from its value in pure copper, passes through a minimum for 6 per cent. arsenic and then increases until the concentration corresponding to the compound Cu_3As is reached. Beyond this concentration the temperature coefficient remains nearly constant.

[129] Puschin and Dischler: *Zeit. anorg. Chem.*, **80**, 65, 1913.

Lead-Magnesium.

The freezing point curve [130] (Fig. 40) shows a maximum corresponding to the compound Mg_2Pb with a eutectic on either side. For concentrations of magnesium less than that corresponding to the compound the alloys are heterogeneous mixtures of lead and

FIG. 40.



Mg_2Pb and for greater concentrations they are mixtures of the compound Mg_2Pb and magnesium.

The curve for electrical conductivities by Stepanow [131] (Fig. 40) shows that the electrical conductivity decreases rapidly with the addition of lead to magnesium until the alloy contains about 5 per cent. lead. At the concentration corresponding to the compound Mg_2Pb the electrical conductivity passes through a minimum.

[130] Grube: *Zeit. anorg. Chem.*, **44**, 117, 1905.
[131] Stepanow: *Zeit. anorg. Chem.*, **78**, 12, 1912.

Magnesium-Copper.

The freezing point curve (Fig. 40) as determined by Urasow [132] and also Sahem [133] shows two maxima corresponding to the intermetallic compounds Cu_2Mg and $CuMg_2$. There are, therefore, in the equilibrium four types of crystalline substances to be considered: Cu, Cu_2Mg, $CuMg_2$ and Mg. None of these substances seems able to form solid solutions with any of the others. The alloys then become divided into three groups, mixtures of Cu with Cu_2Mg; mixtures of Cu_2Mg with $CuMg_2$ and mixtures of Mg and $CuMg_2$.

The electrical conductivity has been measured by Stepanow.[134] He also gives data from which the temperature coefficient can be calculated. These data are, however, very irregular and have not been plotted. Between 100 and 45 per cent. magnesium the curve is nearly a straight line, as it should be for a mechanical mixture of Mg and $CuMg_2$. Between 43 and 20 per cent. magnesium it is again a straight line corresponding to the mixture of $CuMg_2$ and Cu_2Mg. The early part of the curve for small concentrations of magnesium is steep and suggests a solid solution rather than a mechanical mixture.

Antimony-Tellurium.

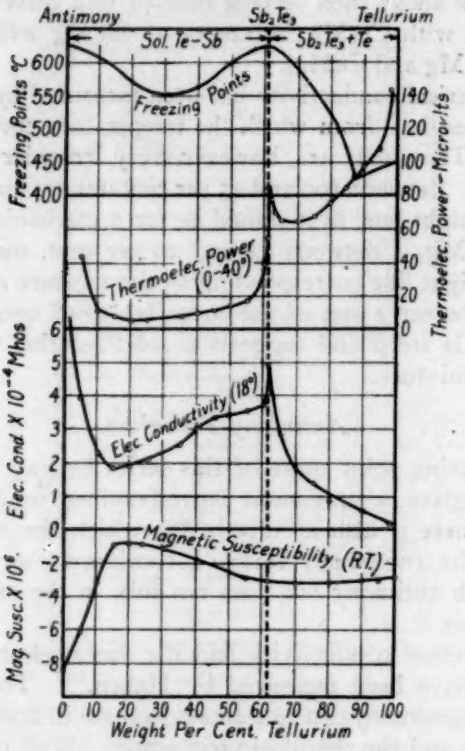
The freezing point curve of this series by Fay and Ashley [135] (Fig. 41) gives a maximum corresponding to the compound Sb_2Te_3. There is also a eutectic for which the temperature is 421° C. The compound forms a continuous series of mixed crystals with antimony but does not mix in the same way with pure tellurium.

The electrical conductivity and the thermoelectric power for this series have been measured by Haken.[136] The addition of tellurium to antimony causes a rapid decrease in both the electrical conductivity and the thermoelectric power. Both of these quantities pass through a minimum and rise rapidly to their value for the compound Sb_2Te_3. The course of these curves between 0 and 60 per cent. tellurium is typical of alloys formed of two crystalline

[132] Urasow: *Jour. russ. Chem. Ges.*, **39**, 1566, 1909.
[133] Sahem: *Zeit. anorg. Chem.*, **57**, 3, 1908.
[134] Stepanow: *Zeit. anorg. Chem.*, **78**, 20, 1912.
[135] Fay and Ashley: *Amer. Chem. Jour.*, **27**, 1902.
[136] Haken: *Ann. d. Phys.*, **32**, 291, 1910.

phases, forming solid solutions. The compound is clearly marked on both curves. The magnetic susceptibility of these alloys has been studied by Honda.[137] Between 100 and 62 per cent. tellurium the curve is nearly a straight line. Over this region the susceptibility varies little. The compound is marked by a sudden change in the direction of the curve at the concentration of the compound.

FIG. 41.



Antimony-Aluminium.

The freezing point curve (Fig. 42) by Gautier[138] has two maxima. One corresponds to the compound AlSb, but the existence of a second compound is questioned.

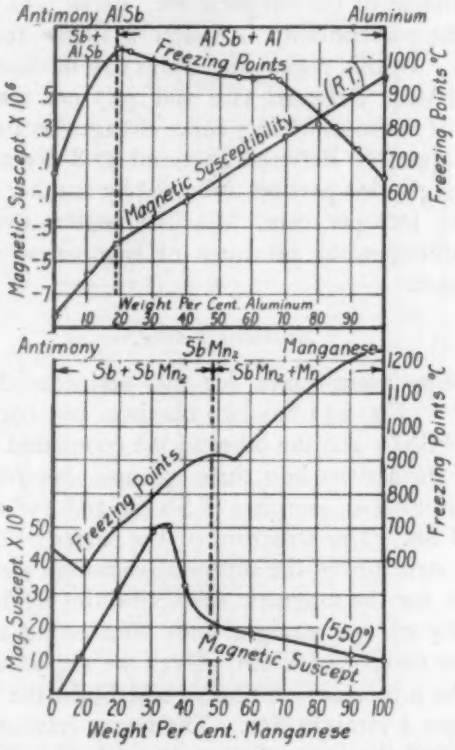
The diamagnetic susceptibility of these alloys has been con-

[137] Honda: *Sci. Rept. Imp. Univ. Tokio*, 2, 9, 1913.

[138] Gautier: "Contribution a l'etude des alleages," 112, 1901.

tributed by Honda.[139] The curve showing the susceptibility as a function of the concentration is made up of two straight lines which intersect where the alloy contains 18.4 per cent. aluminium, *i.e.*, at the concentration for the compound AlSb. The character of the susceptibility curve indicates that alloys containing less than 18.4 per cent. aluminium are mechanical mixtures of anti-

FIG. 42.



mony and the compound AlSb, and those containing more than 18.4 per cent. aluminium are mixtures of aluminium and the compound AlSb.

Antimony-Manganese.

The compound $SbMn_2$ is indicated on the freezing point curve (Fig. 42) by Williams.[140] Between 100 and about 52 per cent.

[139] Honda: *Sci. Rept. Imp. Univ. Tokio*, **2**, 9, 1913.

[140] Williams: *Zeit. anorg. Chem.*, **55**, 1, 1907.

manganese the alloys are heterogeneous mixtures of Mn and the compound $SbMn_2$; between 0 and about 31 per cent. manganese they are a mixture of antimony and a secondary crystalline phase.

The thermal and electrical properties of these alloys have not been studied. The magnetic susceptibility at 550° C. has been determined by Honda.[139] His observations were made with a field of 10.9 kilogausses. The susceptibility for this temperature is nearly independent of the temperature. From 0 to 31.2 per cent. manganese the susceptibility is nearly a linear function of the concentration. In this region the alloys are mechanical mixtures of Sb and $SbMn_2$. Between 31.2 and 40.7 per cent. manganese the character of the susceptibility curve changes because a new crystalline phase appears. Between 40.7 and 47.8 per cent. Mn there is another straight line portion, followed by another linear portion from 50.5 to 100 per cent. Mn, the region over which the alloys are heterogeneous mixtures of manganese and a second crystalline phase.

Antimony-Zinc.

The freezing point curve for this series as determined by Monkmeyer [141] (Fig. 43) has two maxima, one corresponding to the compound SbZn and the other to the compound Sb_3Zn_2. The alloys divide themselves into three groups—heterogeneous mixtures of Zn and Sb_3Zn_2, mixtures of Sb_3Zn_2 and SbZn and mixtures of SbZn and Sb. The structure of the series of alloys is very similar to the structure of the antimony-cadmium series.

The curve for the magnetic susceptibilities by Honda [142] consists essentially of two straight lines intersecting at the concentration for the compound SbZn. Over the region where there is supposed to be a mixture of Sb_3Zn_2 and SbZn the curve departs somewhat from a straight line. The linear relation between the susceptibility and the concentration confirms the existence of the mechanical mixtures indicated by thermal analysis. The curves for the specific resistance, the thermoelectric power and the Hall constant [143] show clearly the compound SbZn, but they give no evidence of the compound Sb_3Zn_2.

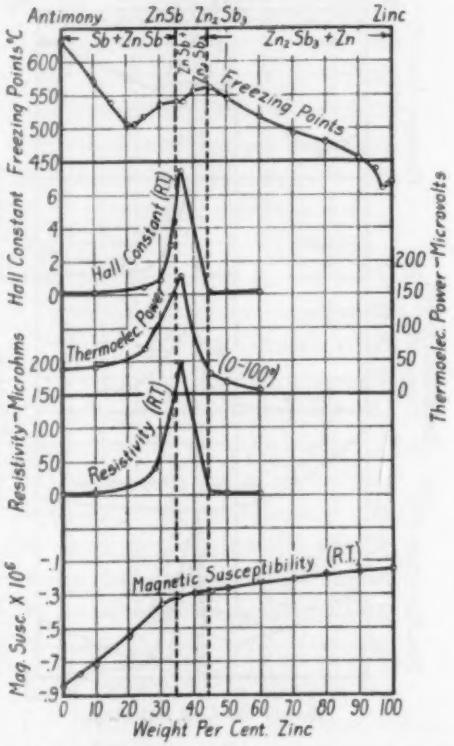
---

[141] Monkmeyer: *Zeit. anorg. Chem.*, **43**, 182, 1905.
[142] Honda: *Sci. Rept. Imp. Univ. Tokio*, **2**, 6, 1913.
[143] Smith: *Phys. Rev.*, **32**, 178, 1911.

Antimony-Cadmium.

The freezing point curve (Fig. 44) by Treitschke [144] gives a compound SbCd which is stable and another Sb_2Cd_3 which is probably unstable. Between 0 and about 40 per cent. antimony the alloys are mixtures of Cd and Sb_2Cd_3; between 40 and 52 per

FIG. 43.



cent. mixtures of SbCd and Sb_2Cd_3 and between 52 and 100 per cent. mixtures of SbCd and Sb.

The curves for the specific resistance, temperature coefficient and thermal conductivity are from the observations of Eucken and Gehlhoff.[145]

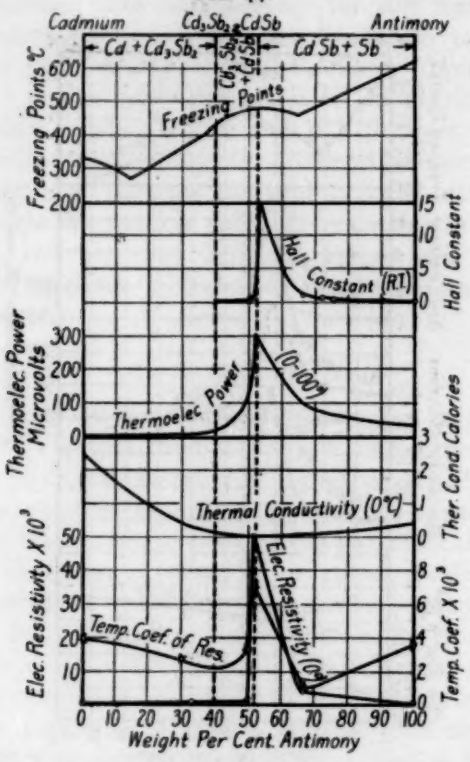
The thermoelectric power of this series has been frequently studied. The curve of thermoelectric powers in Fig. 44 is from

[144] Treitschke: *Zeit. anorg. Chem.*, 50, 217, 1906.

[145] Eucken and Gehlhoff: *Verh. d. deut. Phys. Ges.*, 169, 1912.

Haken.[146] The Hall constant is by the author.[147] The position of the compound is very evident on all of these curves except the curve for the thermal conductivities. On either side of this compound and at some distance from the concentration at which it appears neither the resistance, nor the thermoelectric power, nor

FIG. 44.



the Hall constant changes rapidly with a change in the composition of the alloys.

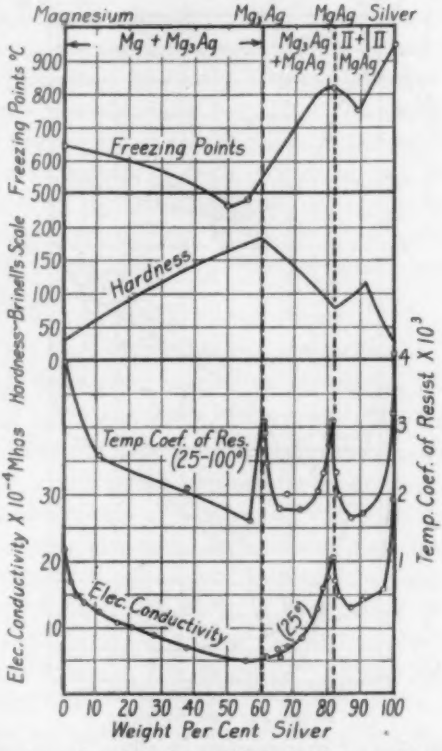
Magnesium-Silver.

The freezing point curve [148] (Fig. 45) gives one maximum at the concentration for the compound MgAg. There is probably a second compound Mg_2Ag. Between 0 and 8.5 per cent. magnesium

[146] Haken: *Ann. d. Phys.*, 32, 291, 1910.
[147] Smith: *Phys. Rev.*, 32, 178, 1911.
[148] Zemczuzny: *Zeit. anorg. Chem.*, 49, 403, 1906.

there is a solid solution of magnesium in silver followed by a mechanical mixture of this solid solution and the compound MgAg. There then follows a region in which there is a mixture of Mg_3Ag and MgAg. Between 0 and 60 per cent. silver the alloys are mixtures of Mg and Mg_3Ag.

FIG. 45.

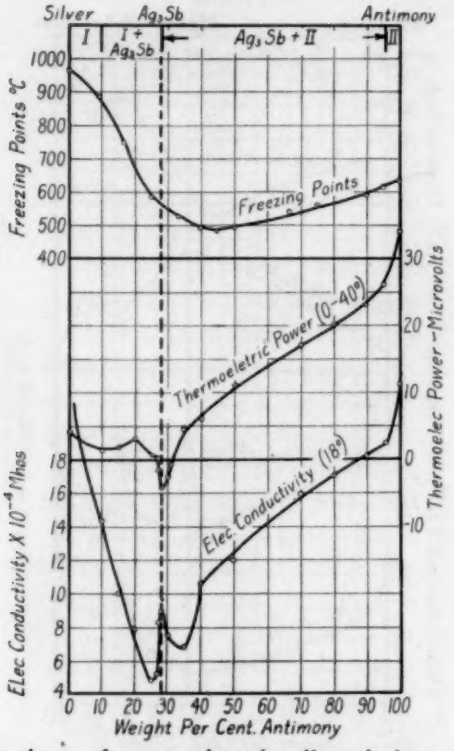


The curve for the hardness [149] of these alloys shows these regions quite clearly. It is made up of four straight lines. One of these lines extends from 0 to 60 per cent. silver, over the region in which the alloys are mechanical mixtures of Mg and Mg_3Ag; the next from 60 to 82 per cent. silver where there is a mixture of MgAg and Mg_3Ag; the third one from 82 to 91 per cent. silver where there is a mixture of MgAg and a saturated solid solution of magnesium in silver; the last from 91 to 100 per cent. silver, the region of the solid solutions of magnesium in silver. The

[149] Desch: "Intermetallic Compounds," p. 15.

curves for the electrical conductivity and the temperature coefficient are by Smirnow and Kurnakow.[150] The positions of both compounds are marked on these curves. The initial rapid decrease in the electrical conductivity and the temperature coefficient for fairly

FIG. 46.



small concentrations of magnesium in silver is in agreement with the conception that solid solutions are formed over this interval. The nearly linear course of these curves between 10 and 58 per cent. silver follows from the fact that the alloys are mechanical mixtures of two crystalline phases over this interval.

Silver-Antimony.

Petrenko [151] gives the freezing point curve (Fig. 46). By a sudden change in curvature it suggests the compound Ag_3Sb. A

[150] Smirnow and Kurnakow: *Zeit. anorg. Chem.*, **72**, 31, 1911.

[151] Petrenko: *Zeit. anorg. Chem.*, **50**, 1906.

solid solution of silver in antimony is formed until the concentration of the silver becomes about 4 per cent. and a solid solution of antimony in silver until the concentration of antimony is about 10 per cent. Between about 10 and 28 per cent. antimony there is a mechanical mixture of Ag_3Sb and a saturated solid solution of antimony in silver and between 28 and 96 per cent. a mixture of Ag_3Sb and a saturated solution of silver in antimony.

The curve for the thermoelectric heights as well as that for the electrical conductivities has been worked out by Haken,[152] and these curves are reproduced in Fig. 46. The compound is clearly indicated and the region in which silver is soluble in antimony is marked by the steepness of both curves in this region. In like manner the interval in which antimony is soluble in silver is indicated by the characteristic drop in the electrical conductivity. The decrease in the thermoelectric power for small concentrations of antimony is less marked.

Aluminium-Copper.

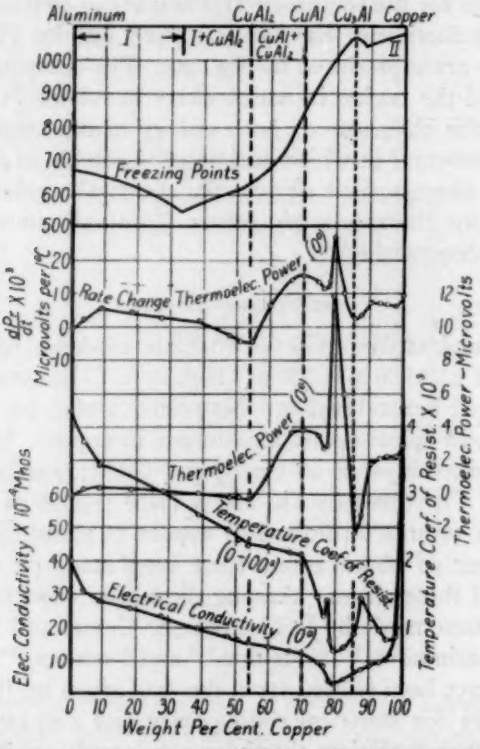
By thermal analysis Gwyer [153] finds evidence of three compounds: Al_2Cu, $AlCu$ and $AlCu_3$ (Fig. 47). The compound Al_2Cu is decomposed before fusion. Between 0 and 9 per cent. copper there are solid solutions of aluminium in copper, followed by a region of mixed crystals of Cu_3Al and $CuAl$; a second region of mixtures of $CuAl$ and $CuAl_2$, and a third region of mixtures of $CuAl_2$ and a saturated solution of copper in aluminium.

A number of observations have been made on the electrical properties of these alloys. Among the earlier observations in this region are those made by LeChatelier,[154] Dewar and Flemming,[155] Battelli,[156] Steinmann,[157] Pouchine [158] and Pecheux.[159] The curves in Fig. 47 have been plotted from the data given by Broniewski.[160] On the curve for electrical conductivity and also on the one for the temperature coefficient the three compounds are indicated by a

[152] Haken: *Ann. d. Phys.*, **32**, 291, 1910.
[153] Gwyer: *Zeit. anorg. Chem.*, **57**, 113, 1908.
[154] LeChatelier: *C. R.*, **101**, 454, 1890.
[155] Dewar and Flemming: *Phil. Mag.* (5), **36**, 271, 1893.
[156] Battelli: *Atti. R. Inst. Veneti.* (6), **5**, 1148, 1886–7.
[157] Steinmann: *C. R.*, **130**, 1300, 1900.
[158] Pouchine: *Jour. Soc. phys. Chem. russ.*, **39**, 528, 1907.
[159] Pecheux: *C. R.*, **148**, 1041, 1909.
[160] Broniewski: *Ann. de Phys. et Chem.* (8), **25**, 91, 1912.

change in the slope of the curves at the concentrations corresponding to the compounds. On the curve for the thermoelectric power and also on the curve for the variations of the thermoelectric power with the temperature the compounds Al_2Cu and $AlCu_3$ are marked by minima in the curves. Over the region between 91 and 100 per cent. copper where solid solutions of aluminium in copper

FIG. 47.



are formed the electrical conductivity and the temperature coefficient show the decreases characteristic of such solutions.

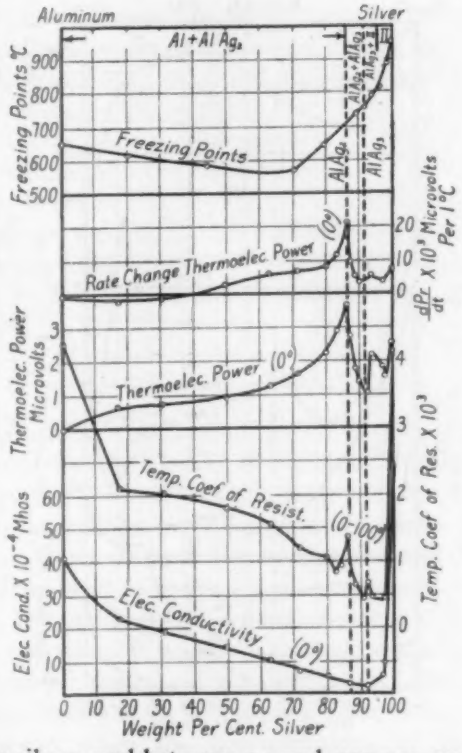
Aluminium-Silver.

The freezing point curve (Fig. 48) by Petrenko [161] gives two compounds, $AlAg_2$ and $AlAg_3$. These compounds are indicated by a change in the curvature of the freezing point curve at the concentration at which the compound occurs. This change in curvature is

[161] Petrenko: *Zeit. anorg. Chem.*, 46, 49, 1905.

not very evident from the curve as plotted in Fig. 48. Between 0 and 87.5 per cent. silver the alloys are mechanical mixtures of aluminium and the compound $AlAg_2$; between 87.5 and 91.5 per cent. silver mixed crystals of $AlAg_2$ and $AlAg_3$; between 91.5 and 94 per cent. silver mixtures of $AlAg_3$ and saturated solid solutions of

FIG. 48.



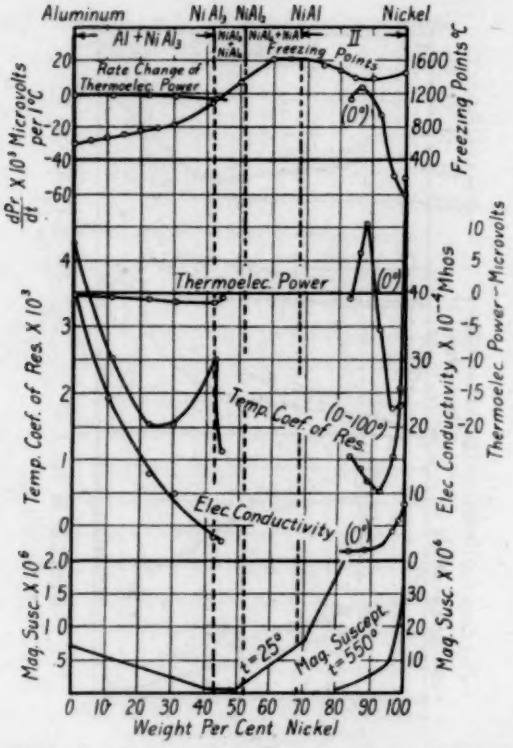
aluminium in silver, and between 94 and 100 per cent. silver solid solutions of aluminium in silver.

The curves for the electrical conductivity, temperature coefficient, thermoelectric power and variations of the thermoelectric power with the temperature have been taken from the observations of Broniewski.[162] The compound $AlAg_2$ is marked clearly by a peak in each of the curves except the curve for the electrical conductivity where the peak is small. On the other hand, a

[162] Broniewski: *Ann. de Phys. et Chem.* (8), **25**, 83, 1912.

minimum occurs in each of the curves except the curve for electrical conductivities where the concentration corresponds to the compound $AlAg_3$. Except for the two peaks in the curve for the temperature coefficient that curve as well as the curve for electrical conductivities has the form which is found in binary alloys

FIG. 49.



of metals which form limited solid solutions with each other and then these solid solutions mix mechanically to form the remainder of the alloys of the series.

Aluminium-Nickel.

The freezing point curve (Fig. 49) by Gwyer [163] gives a maximum near the concentration corresponding to the compound NiAl. Between 0 and 42 per cent. nickel the alloys are mixtures of Al

[163] Gwyer: *Zeit. anorg. Chem.*, **57**, 133, 1908.

and $NiAl_3$; between 42 and 52 per cent. nickel mixtures of $NiAl_3$ and $NiAl_2$; between 52 and 68 per cent. nickel mixtures of $NiAl_2$ and NiAl, and between 68 and 100 per cent. nickel an unsaturated solution of aluminium in nickel.

The electrical conductivity, the temperature coefficient, the thermoelectric power and its variation with the temperature have been plotted from the observations of Broniewski.[164] In the interval between 45 and 84 per cent. nickel there are no observations on account of the brittleness of the alloys in this region. The compound $NiAl_3$ is indicated by a peak on the temperature coefficient curve. The magnetic susceptibilities by Honda [165] have been measured at 25° C. for alloys containing less than 80 per cent. nickel. For alloys containing more than 80 per cent. nickel the susceptibilities were determined at 550° C. A magnetic field of from 5 to 12 kilogausses was used. Until the alloys contain 80 per cent. nickel the susceptibility curve consists of four straight lines intersecting at the concentrations at which a new crystalline phase appears.

Nickel-Tin.

The composition of this series of alloys is very complex. The freezing point curve by Gautier [166] has been reproduced in Fig. 50. Five different kinds of crystals are present in the solidified alloys.

No observations have been found on the thermal and electrical properties of these alloys. The magnetic properties have been studied by Honda.[165] On the alloys containing less than 60 per cent. nickel the observations were made at 25° C. On the remainder of the alloys the observations were made at 550° C.—a temperature above the transformation point. The external magnetic field was from 5 to 12 kilogausses. The ferro-magnetic properties disappear when the concentrations of the constituents correspond to the compound Ni_3Sn. So long as the alloys are composed of the same two kinds of crystals in varying concentrations the susceptibility is a linear function of the concentration. Where one type of crystal disappears and is replaced by another the slope of the curve suddenly changes.

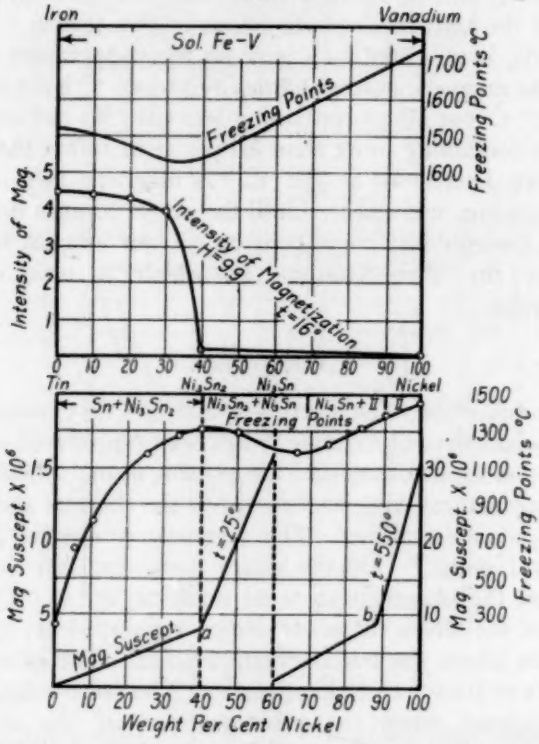
---

[164] Broniewski: *Ann. de Chem. et Phys.* (8), **25**, 108, 1912.
[165] Honda: *Ann. d. Phys.*, **32**, 1015, 1910.
[166] Gautier: *C. R.*, **122**, 109.

Iron-Vanadium.

The composition of iron and vanadium alloys has been studied by Vogel and Tammann,[167] and it has been found that they solidify in the form of an unbroken series of mixed crystals. The freezing point curve (Fig. 50) has a minimum in the neighborhood of 35 per cent. vanadium.

FIG. 50.



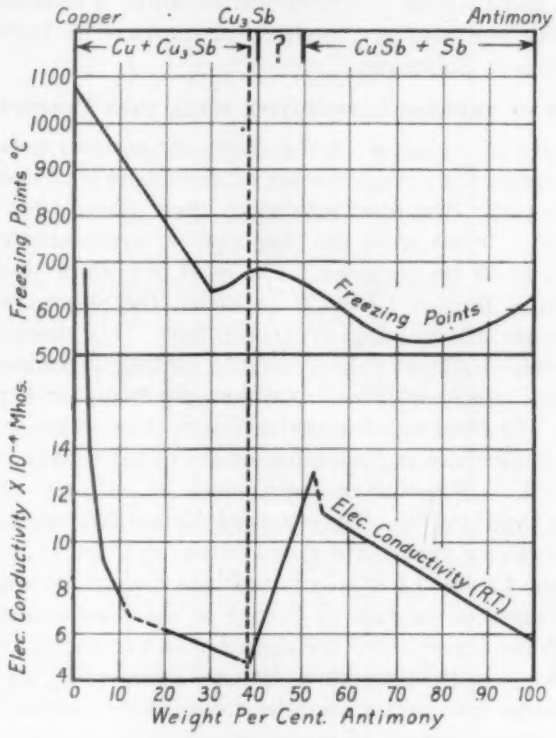
The electrical and thermal properties of this series of alloys do not seem to have been studied. There are observations by Honda [168] on the intensity of magnetization. These observations were made at 16° C. and with a magnetic field of 9.9 gausses. The intensity of magnetization of iron decreases slowly with an increasing concentration of vanadium until that concentration is

[167] Vogel and Tammann: *Zeit. anorg. Chem.*, **58**, 79, 1908.

[168] Honda: *Ann. d. Phys.*, **32**, 1910, 1912.

reached at which the freezing point curve has its minimum. Here there is an extraordinarily rapid decrease in the intensity of magnetization so that an alloy containing more than 40 per cent. of vanadium is very feebly magnetic.

FIG. 51.



Copper-Antimony.

Baikow [169] has given a complete equilibrium diagram from which the freezing point curve (Fig. 51) is taken. The compound Cu_3Sb is formed. Alloys to the right or left of this compound are heterogeneous mixtures of two crystalline phases. Copper, according to Stead, dissolves about 0.3 per cent. antimony.

For small concentrations of antimony the electrical conductivity curve by Matthiessen [170] is very steep. This is in the region

[169] Baikow: *Jour. reiss. Phys. Chem. Ges.*, **36**, 111, 1904.

[170] Matthiessen: *Pogg. Ann.*, **110**, 190, 1860.

where antimony and copper form dilute solid solutions. The electrical conductivity curve shows a sudden change in direction where the concentrations correspond to the compound Cu_3Sb. Between 55 and 100 per cent. antimony the conductivity curve is a straight line. Over this interval the alloys are mechanical mixtures. A third region of mechanical mixtures is indicated by the straight line representing the electrical conductivity between 38.4 and 52 per cent. antimony.

CHANGE OF THERMOELECTROMOTIVE FORCE WITH TEMPERATURE.

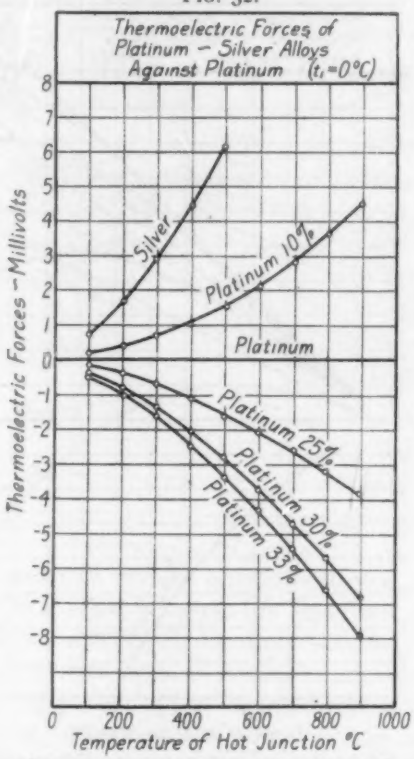
The rate of variation of the thermoelectromotive force with the temperature for a large number of aluminium alloys has already been discussed. The observations on these alloys were made by Broniewski. In his work the observations were extended over a limited range of temperature. The most important work in this connection is that of Giebel,[171] in which the observations were extended over a large range of temperature. He studied the following series of alloys: Palladium-gold, palladium-platinum, palladium-silver, platinum-silver, platinum-rhodium, and platinum-iridium. The thermoelectromotive forces were measured against platinum in this case and the temperature of the cold junction was kept at 0° C. Observations were made at intervals of 100° C. between 0° and 900° C. The observed thermoelectromotive forces have been plotted against the temperatures in Figs. 52, 53 and 54. From Figs. 52 and 54 it is seen that the higher the temperature the more rapid is the rate of change of the thermoelectromotive force with the temperature for palladium-silver and for platinum-silver alloys. In the palladium-platinum series (Fig. 53) there is nearly a linear relation between the thermoelectromotive force and the temperature after the alloy contains about 40 per cent. platinum. When the concentration of platinum is increased above 40 per cent. this linear relation is more nearly realized.

In Fig. 55 the thermoelectromotive force in platinum-rhodium alloy at a particular temperature has been plotted against the concentration of rhodium in the alloy. These curves show that the thermoelectromotive force increases rapidly with the increase in the concentration of rhodium until the alloy contains about 5 per cent rhodium. Between 5 and 10 per cent. rhodium the increase is much less rapid, especially at low temperatures. Increasing the

[171] Giebel: *Zeit. anorg. Chem.*, **69**, 38, 1910, and **70**, 240, 1911.

concentration of rhodium beyond 10 per cent. changes only slightly the thermoelectromotive force until the temperature of the hot junction exceeds 1000° C. At very high temperatures the thermoelectromotive force continues to increase with increasing concentration of rhodium, but this rate of increase decreases with increasing concentration of rhodium.

FIG. 52.



The relation between the thermoelectromotive force and the difference in temperature between the junctions may be expressed by an equation of the form

$$E = a\,t + b\,t^2 + c\,t^3$$

where one junction is kept at $o°$ C. and the other at $t°$ C. For a large number of metals and alloys it has been found that only the second power of the temperature need be considered. The equation then becomes, to a very good approximation,

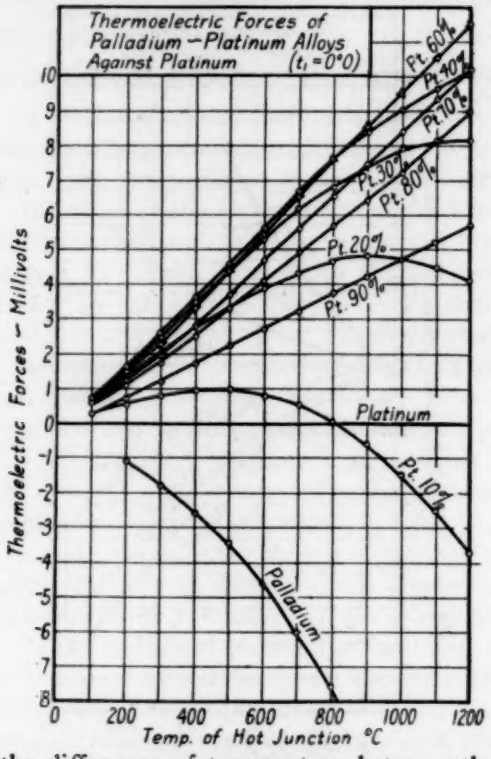
$$E = a\,t + b\,t^2.$$

In such a case the rate of variation of the thermoelectromotive force with the temperature becomes

$$\frac{d\,E}{d\,t} = P = a + 2\,b\,t.$$

This equation states that the thermoelectric power is a linear

FIG. 53.



function of the difference of temperature between the junctions. In some of the platinum-palladium alloys it has already been seen to be independent of the temperature. The rate of variation of the thermoelectric power with the temperature is

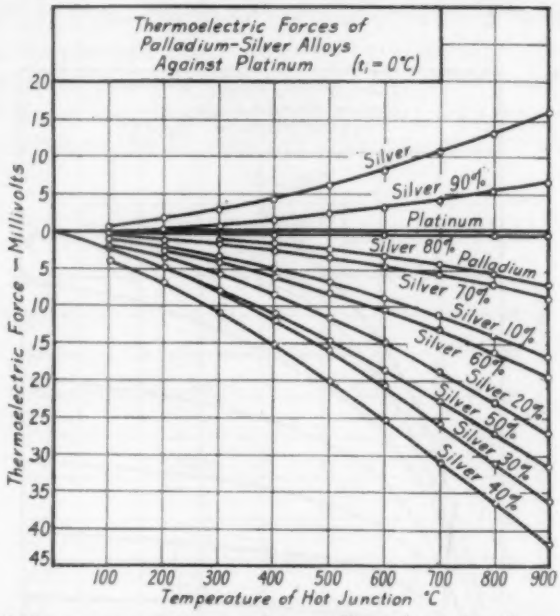
$$\frac{d\,P}{d\,t} = 2\,b.$$

In so far as the approximation introduced above is correct the variation of the thermoelectric power with the temperature is the same for all temperatures.

THEORIES OF RESISTANCE AND THERMOELECTROMOTIVE FORCES.

Lord Rayleigh [172] and Liebenow,[173] independent of each other, came to the conclusion that the increase in specific resistance which alloys show in excess of the resistance calculated from the resist-

FIG. 54.

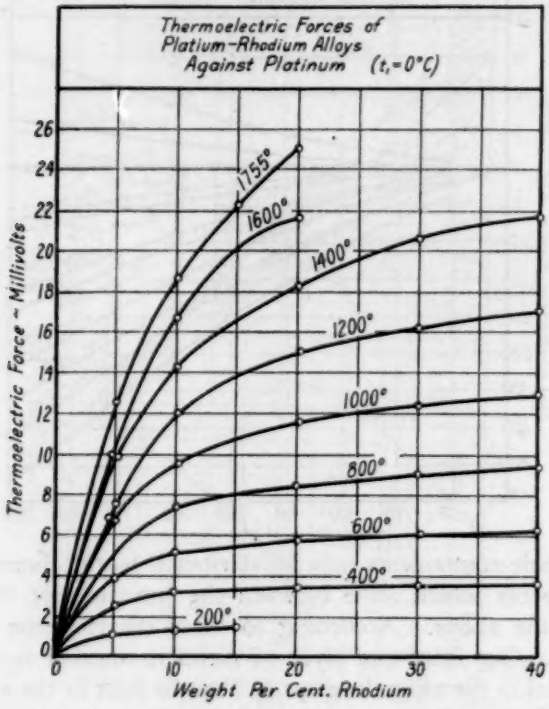


ance of their components may be attributed to the thermoelectromotive forces which arise between the junctions of the metals forming the alloys. According to these theories, the electrical current passing from one layer of metal to another layer of the other metal in the alloy develops or absorbs heat at the surface of contact between the components of the alloy, on account of the Peltier effect. These temperature differences cause thermoelectromotive forces to be set up in the alloy in such a way that they are equivalent to a large number of small cells connected in series, so that they oppose the flow of the current through the substance. They have, therefore, the effect of an added resistance. Since the difference in temperature between the contacts is proportional to the current flowing in the conductor, and since the thermoelectro-

[172] Lord Rayleigh: *Nature*, **54**, 154, 1896.
[173] Liebenow: *Zeit. Electrochem.*, **4**, 201 and 217.

motive forces are proportional to the difference in temperature, this back electromotive force is proportional to the current. The opposition to the flow of current through the alloy from this cause will, therefore, behave like a resistance and it will be impossible to distinguish between the ordinary resistance and that which arises from these thermoelectromotive forces. It is of importance

FIG. 55.

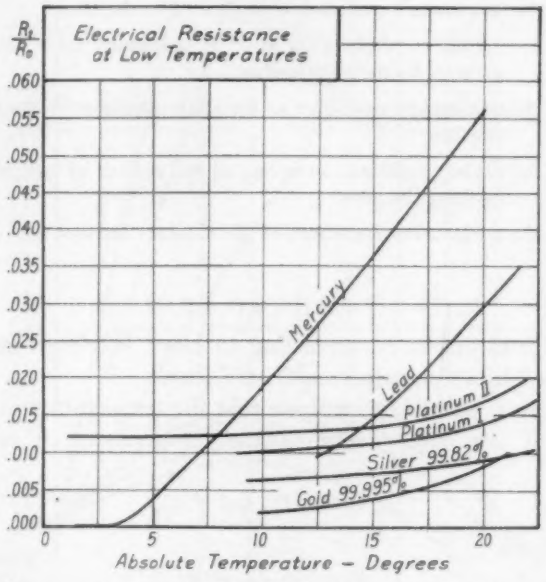


to note that where the constituents form compounds in which the resistance is high, it is necessary on the basis of this theory to assume a thermoelectromotive force between the molecules. Such an assumption is not very probable.

Some evidence for the correctness of this theory is found in the consideration of the way in which the electrical resistance of metals and alloys behaves at extremely low temperatures. When the temperature of a pure metal is decreased, the electrical resist- temperature, until the temperature is 3 or 4 degrees above the ance is found to be very accurately proportional to the absolute

absolute zero where the superconducting state appears and the electrical resistance almost entirely disappears. If, on the other hand, the temperature of an impure metal or alloy is decreased indefinitely, the resistance does not disappear at the absolute zero, but approaches a constant value. This suggests that there is in the resistance of an alloy an added constant term which does not disappear at the absolute zero. The theory of Lord Rayleigh leads at once to the existence of such a term. The added resistance arising from the causes considered in this theory does not seem large enough to account for the very high resistance of some alloys.

FIG. 56.



By reference to Fig. 56 it will be seen that the curve showing the relation between the electrical resistance of mercury and its temperature is nearly a straight line except near the origin. The curve for pure lead is also observed to be a straight line, but the corresponding curves for metals containing small admixtures of other metals do not seem to pass through the origin when prolonged backward. In such cases the electrical resistance seems to approach a constant value which persists to the absolute zero. Such a constant value is to be expected on the basis of the theory proposed by Lord Rayleigh and may, therefore, be taken as par-

tial evidence of the correctness of that theory. From the above point of view it is clear that it is impossible to prepare a good conductor by mixing two or more metals with each other. There will always be present this added resistance which makes the alloy at least not a better conductor than the constituents of which it is composed. Ordinarily the alloy is found to have a lower conductivity than would be calculated from its constituents by the additive law.

This theory of Lord Rayleigh may be stated more fully as follows:

Let R_0 = the resistance of the alloy at 0° C.

γ = the temperature coefficient of resistance of the alloy.

R = the resistance of the alloy at 0° C. calculated from its constituents by the additive law.

α = the temperature coefficient of the alloy calculated by the additive law.

R_c = the contact resistance occurring at the surface of two metals forming the alloy.

β = the temperature coefficient of the constant resistance.

Then,

$$R_0 (1+\gamma t) = R (1+\alpha t) + R_c (1+\beta t).$$

The resistance R_c is, according to Lord Rayleigh and Liebenow, caused by thermoelectromotive forces.

Where it is possible to assume that the temperature coefficients γ, α and β are independent of the temperature, it is possible to write,

$$R_0 = R + R_c, \text{ and } 0° \text{ C.},$$

and therefore,

$$R_0 \gamma = R \alpha + R_c \beta,$$

at any temperature.

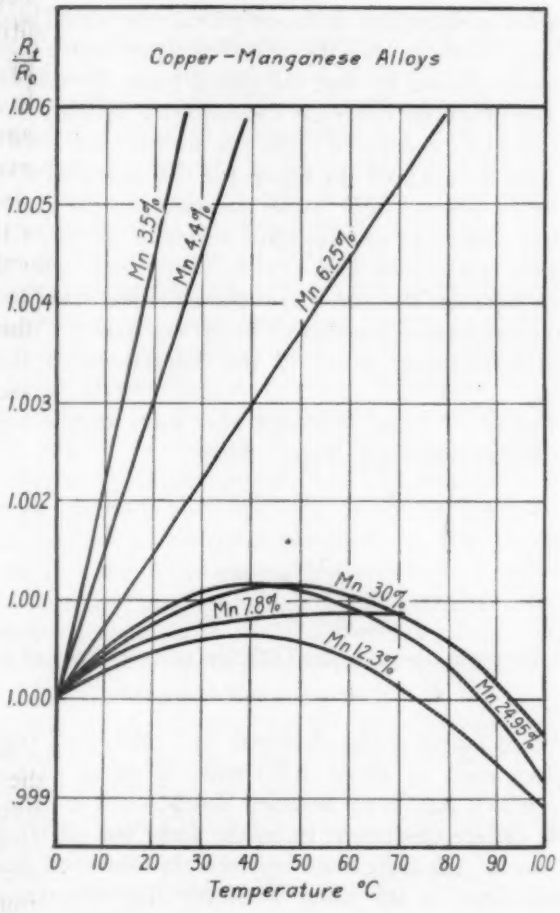
Whence,

$$\gamma = \frac{R \alpha + R_c \beta}{R_0}.$$

From this equation it is seen that γ may be negative when β is negative and $R_c \beta > R\alpha$. The temperature coefficient of alloys has been found negative in some cases. A well-known example is the case of copper-manganese alloys. Curves showing the ratio of the resistance at any temperature to the resistance at zero for some

copper-manganese alloys have been reproduced in Fig. 57. They are taken from the work of Guertler.[174] For an alloy containing 12.3 per cent. of manganese the temperature coefficient is positive above and negative below 40° C.

FIG. 57.



If it is possible to assume that $\beta = o$, that is, that the contact resistance is independent of the temperature,

$$R_o (1 + \gamma t) = R (1 + \alpha t) + R_c,$$

[174] Guertler: *Jahr. der Rad. und Elekt.*, 5, 17, 1908.

and since

$$R_0 = R + R_c,$$

$$R_0 \gamma = R \alpha$$

$$\frac{R_0}{R} = \frac{\alpha}{\gamma}.$$

This equation is equivalent to the empirical rule stated by Matthiessen and Vogt; namely, that the observed temperature coefficient of the resistance divided by that calculated from the additive law is equal to the observed electrical conductivity divided by the electrical conductivity calculated from the additive law. In so far as this rule may be accepted the curve for the electrical conductivity of a series of alloys ought to be the same as the curve for the temperature coefficient of that same series of alloys. In the preceding pages it has been seen that in very many cases there is a parallelism between the curve for the electrical conductivity and that for the temperature coefficient of the resistance. This parallelism offers satisfactory proof of the correctness of this rule in many cases.

The theory of Lord Rayleigh also leads to the second rule stated by Matthiessen and Vogt. Since

$$R_0 (+ l\gamma t) = R (l + \alpha t) + R_c,$$

and

$$R_0 = R + R_c,$$

$$R_c = R_0 - R =$$

difference between observed and calculated resistance at 0° C., and

$$R_c = R_0 (l + \gamma t) - R (l + \alpha t) =$$

the difference between the observed and calculated resistance at t° C. Since each of these differences is equal to the contact resistance which has been assumed independent of the temperature, these differences ought to be the same for all temperatures. In other words, the difference between the observed and the calculated resistance is the same whatever the temperature. The large number of cases in which this rule has been found to be verified gives evidence that the temperature coefficient of the contact resistance is either zero or very small.

The increase in the electrical resistance of solid solutions over the resistance of the pure metals of which they are composed does

not find an easy explanation on the basis of the electron theory of metallic conduction. One assumption which has been made to explain this increase is that the number of free electrons in the alloy is much less than in pure metals. This assumption when considered in connection with Wiedemann and Franz's law does not lead to satisfactory results. The departures from this law, which states that the ratio of the thermal to the electrical conductivity is a constant for any particular temperature, are greater for alloys than for pure metals. These departures are always of such a nature that the electrical conductivity has been decreased more than the thermal conductivity by the formation of the alloy. This, with other considerations, has lead Schenck [175] to suggest that the increase in the electrical resistance of the alloy over the value calculated by the additive law could be accounted for by assuming that it arises from an increase in the frictional resistance which the electrons encounter in their motion through the alloy. This increase in frictional resistance to the motion of the electrons may be thought of as produced in a way very analogous to the way in which on the basis of the kinetic theory the addition of one gas to another causes an increase in the viscosity. Schenck thinks that the slowly diffusing molecules of the added metal hand on their energy and thus participate in the thermal conductivity but not in the process of electrical conduction. For this reason the ratio of the thermal to the electrical conductivity in mixed crystals is greater than for pure metals, and this quotient increases with increasing concentration of the added metal. The ratio of these conductivities in alloys as in pure metals is approximately proportional to the absolute temperature.

According to the electron theory, the different concentration of the electrons in the two metals is the source of a diffusion current which is the cause of the thermoelectromotive force which arises when the junctions of two metals or alloys are at different temperatures.

Let e = the thermoelectromotive force per degree difference in temperature.
R = the gas constant in ergs.
F = 965,450 coulombs.
N_a = number of electrons per cubic centimetre in A.
N_b = number of electrons per cubic centimetre in B.

[175] Schenck: *Ann. d. Phys.*, **32**, 261, 1910.

Then,

$$e = \frac{R}{F} \text{Log}_e \frac{N_a}{N_b}.$$

Many alloys give such large values of the thermoelectromotive force against one of the pure metals of which they are composed that in the application of the above equation it is necessary to assume very large changes in the number of free electrons to be produced by adding one metal to the other. In order to avoid these improbable assumptions Schenck has introduced the assumption already referred to—that it is the friction of the free electrons rather than their number that is changed by alloying one metal with another. By using this assumption that there is an increase in the frictional resistance of the electrons in the alloys over the resistance which they experience in pure metals, Schenck has been able to derive a relation between the thermal and electrical conductivity of the alloy, the thermal and electrical conductivity of the pure metallic solvent, and the thermoelectric power of the alloy against the pure solvent.

Let k = thermal conductivity of the pure solvent.

σ = electrical conductivity of the pure solvent.

k' = the thermal conductivity of the alloy.

σ' = the electrical conductivity of the alloy.

π = the thermo-electromotive force of the solid solution against the pure solvent for 1° C. temperature difference between the junctions.

R = the gas constant.

e = the specific electrical charge = 96,540 coulombs.

Then for dilute solutions Schenck shows that

$$\pi = \frac{R}{2e} \text{Log}_e \left(\frac{k'}{\sigma'} \div \frac{k}{\sigma} \right).$$

Some observations have been made by Bernoulli [176] to test the validity of this equation. The following table shows the kind of agreement which exists between the observed and calculated values.

[176] Bernoulli: *Ann. d. Phys.*, 33, 690, 1910.

Solvent.	Element in solution.	π Observed.	π Calculated.
Silver	2.73 per cent. Th.	2.8	2.6
	4.76 per cent. Th.	10.3	8.4
	4.00 per cent. Sn.	7.6	8.9
Cadmium.....	5.14 per cent. Hg.	2.8	2.2
	10.0 per cent. Hg.	2.6	3.0
Copper	5.00 per cent. Sn.	3.4	3.6
	3.11 per cent. Zn.	2.9	3.6
	5.00 per cent. Zn.	1.4	6.6
	3.94 per cent. Ni.	13.3	3.9
	17.30 per cent. Ni.	27.3	11.2

From this table it is seen that for dilute solutions fair agreement exists between the observed and the calculated values. The more concentrated the solution the less satisfactory is the agreement.

RESISTANCE AND HARDNESS.

A theory of electrical conductivity proposed by March [177] offers a possible explanation of the relation between the elastic properties and the electrical conductivity of alloys. According to this theory, the number of free electrons in a metal or alloy, and therefore the electrical conductivity, is in part, at least, determined by the characteristic frequency of vibration of the atoms about their positions of equilibrium. Whatever changes this characteristic frequency would change at the same time the elastic properties and the thermal and electrical properties. On the basis of this theory the number of free electrons decrease with increasing frequency of the characteristic vibration of the atoms. Whatever, therefore, decreases the frequency of the characteristic vibrations of the atoms increases the electrical conductivity of the substance. Hence, at the absolute zero where the characteristic frequency of vibration of the atoms is very small or else disappears, the electrical conductivity will be very large. This is, of course, exactly what is observed in metals at very low temperatures where they pass into the superconducting state.

The formation of a solid solution produces a change in the elastic properties which causes the characteristic frequency of vibration of the atoms to increase. This arises out of the fact

[177] March: *Ann. d. Phys.*, **49**, 710, 1916.

that in an alloy in which the components A and B form mixed crystals, a molecule of A and a molecule of B act on each other with greater force than that with which a molecule of A acts on a molecule of A or a molecule of B on a molecule of B. There is on this account an increase in the cohesive forces and consequently an increase in the characteristic frequency of vibration of the atoms. With this increase in frequency is associated a decrease in the number of free electrons and a corresponding increase in the electrical resistance. From this point of view it is possible to see that where such elastic properties as hardness or tensile strength have maximum values, the electrical resistance will have a maximum value and the electrical conductivity a minimum value. Many illustrations of this have been seen in the preceding curves.

If the two components A and B of the alloy are insoluble in each other, the force which the molecule A exerts on another molecule A or the force which a molecule B exerts on another molecule B exceeds the force which a molecule A exerts on a molecule B or that which a molecule B exerts on a molecule A. Consequently each of these classes of molecules will form a group of crystals and the alloy will be a conglomerate formed of groups of crystals of the two constituents. In such an alloy the characteristics of each constituent are retained and the physical properties are additive. The components will, therefore, retain their characteristic vibrations and their elastic properties as well as the number of free electrons, and the electrical conductivity will change in conformity to the additive law. The hardness which increases with the frequency of the characteristic vibration of the atoms should in such cases be a linear function of the concentration of one of the constituents in the alloy. In such alloys the electrical conductivity will also be a linear function of the concentration of one of the constituents. Many cases of this kind have been noted in the preceding pages. This theory seems to offer a possible explanation of some of the interesting relations noted among the physical properties of alloys. Although the theory may not be satisfactory in many particulars, it is without doubt very suggestive.

Grateful acknowledgment is made to the Engineering Experiment Station of the Ohio State University for generous financial assistance in aid of this work.

PHYSICAL LABORATORY,
OHIO STATE UNIVERSITY.

INTERNAL COMBUSTION ENGINES IN MARINE SERVICE.*†

BY

CHARLES EDWARD LUCKE.

Professor of Mechanical Engineering, Columbia University, N. Y. C.
Consulting Engineer, Worthington Pump and Machinery Corporation
Member of the Institute

PART II.

NEW STANDARDS OF TURBINE STEAMER AND MOTORSHIP MACHINERY COMPARED.

THE conclusions so far established, while pretty clear as to the relative value of the present standards of single-screw geared turbine with steam auxiliaries, and twin-screw, direct-coupled Diesel engines and Diesel electric auxiliaries, will be changed by new plans for using turbines and oil engines now under experimental trial or in prospect. However clear a justification may be found for a construction program based on economic zones of present machinery standards, conclusions must be checked against other possibilities that are available before adoption as a guide. This requires a review of these proposals, and a selection of that one in each of the two classes that seems to be most prominently under consideration, for a new comparison of turbine and oil-engine power, representative of the immediate future.

Steam-turbine propulsion has been studied in every possible variation of main and auxiliary machinery, and in many cases trial installations have been made. Some of these plans are found to be non-competitive with reference to the rest and need not be considered. Those that seem to promise results that compete better with the motorship are the ones that *reduce fuel consumption*, even at increased first cost and machinery weight, thus adopting some of the motorship advantages.

Steam consumption of the main turbine can be reduced only by changing pressure and superheat, or by an increase of speed beyond what has so far been regarded as suitable for gear reduc-

* Presented at the Stated Meeting of the Institute held Wednesday, April 20, 1921.

† Concluded from page 45, vol. 192, July, 1921.

tion. The best turbine speed set by the Bĕrg standard is 4030 R.P.M. for 4000 horsepower, to give least possible fuel consumption. This speed is higher than has so far seemed good for gearing, but is well adapted to a turbogenerator unit, as the generating element of electric drive. With such a high-speed turbogenerator unit some small gain in steam consumption can be secured. Higher steam pressures than 200 lbs. are not practical without a change in boiler cost, weight or type, and must be set aside for the present, but with it superheat of 200° F. is feasible and will help, especially with the turbo-electric drive which eliminates the reversing turbine. No gain in vacuum over the 28.5″ standard seems practicable without proportionately greater expense.

There is a much greater possibility of savings in modifying the auxiliaries than by raising speed and superheat of the main turbine, because of the great inefficiency of direct acting steam auxiliaries that will take from 12 per cent. to 20 per cent. of the steam used by the main unit, depending on conditions. Prospects of reducing this are best, when all auxiliaries are electrified, as this permits the use of an economical, electric generating set. A small, steam-turbine generating set will operate motor-driven pumps, winches and steering gear more economically than is possible by individual steam cylinders, besides carrying lighting and exciter loads, but at a greater installation cost. Once the auxiliaries are electrified, any other auxiliary generating set can be used and the most economical from the fuel point of view is the Diesel engine-driven generator.

Adoption of the Diesel engine generating set for operating motor-driven auxiliaries will reduce the auxiliary fuel consumption to the least possible, and make it practically the same as for the motorship except as loads differ slightly for steam condenser pumps against jacket circulating pumps, for example. Similarly, the adoption of the high-speed turbogenerator as the main unit for electric-drive propulsion will reduce the fuel consumption of this main unit to a minimum, the generator motor losses being substantially equal to the gears of the geared turbine drive.

This combination gives the lowest possible fuel consumption for a turbine ship and is, therefore, adopted as a standard of reference for the future to be compared with the new standard of Diesel engine arrangement.

Such a steam-turbine, electric-drive ship with Diesel electric

auxiliaries will give a fuel consumption for all purposes at sea under normal working conditions of about .95 lb. of fuel oil per hour per S.H.P., which is somewhat less than 20 per cent. over the test value to allow for expected derangements of adjustments or condition of equipment. In port the fuel consumption will be substantially the same as for the Diesel ship, which is .6 ton per day, or 12 tons per port call of 20 days, equivalent to 79 barrels.

TABLE XIV.

Equipment List for Installation of Single-Screw Steam Turbine Electric Drive, 200 lbs. Steam Pressure, 200° Superheat, 28.5" Vacuum, 3500 S. H. P. at 90-100 R. P. M., Motor Aft., with Diesel Electric Auxiliaries.

Group	Equipment Item	Weight Tons	Cost Dollars
A	One 4100 H. P., 3500 S. H. P. turbogenerator set (A. C.) complete with controls	47.00	$50,000
B	Three Scotch boilers, full, complete with superheaters, stack, fuel oil, burner set, fuel and feed pumps and feed heater	320.00	80,000
C	Fresh water system, tank evaporator and distiller	6.00	1,500
D	Engine room power auxiliaries, condenser, pumps motor driven	23.00	23,000
E	Engine room ship auxiliaries, ballast, fire and bilge, sanitary, bilge and fresh water pumps, motor driven.	6.00	2,900
F	Three Diesel electric generating sets, 150 H. P. complete with air bottle, silencers and piping	66.00	48,000
G	One 50 H. P. oil engine emergency generating set with air compressor	6.00	6,000
H	Fixed engine and boiler room equipment, platforms, piping, full, tanks, spares, tools, stores	40.00	36,000
I	Deck auxiliaries, ten electric winches with windlass and steering gear	60.00	60,000
J	Power transmission—one 3500 H. P. motor complete with ventilation, mounting, shafts, bearings and propeller	85 00	63,000
	Total	659.00	$372,400
	Total per H. P.	.188 tons	$106.00

The electric-drive equipment of the turbine ship with Diesel electric auxiliaries will weigh more and cost more, than that of the gear drive with steam auxiliaries, and these items are to be balanced against the lower fuel consumption, which adds freight earnings, due to less fuel weight to be carried, and reduces expenses by the money value of the fuel saving.

The weights and costs of the various items of the equipment are collected in Table XIV, which, compared with Table I, shows

that the weight is 95 tons, or 2.7 per cent., heavier than the gear drive, and the cost $95,300, or 34 per cent., higher than the gear drive.

The calculations of cargo-capacity, yearly income from freight carried, disbursements and undistributed returns on capital investment, are taken up later, after the selection of a corresponding new type of Diesel ship with which this turbine electric drive is to be compared as to economic zones.

Modifications of Diesel oil engines, of propellor drives for oil engines, and of auxiliaries for such ships, over the previous standard of twin direct-coupled, four-cycle, air-injection, direct-reversing models with Diesel electric auxiliaries, are available in most bewildering variety. Some of these are just different, with no definite prospect of more economical cargo carrying than the present standard direct-coupled Diesel engine, nor any extension of its economical zone into that of the turbine ship. These novelties are natural in so young an art as that of oil engine construction, some of them may develop into something of real value, but for the present and for the immediate future, those modifications of existing standards that are worthy of immediate consideration are the ones that can meet the conditions as they are.

The conditions to be fulfilled are primarily—*reduction of cost and weight* of Diesel equipment, with the least possible sacrifice of fuel consumption and other existing features of merit that have been so far established. The prime consideration seems to be reduction of weight and cost of equipment, with space also important as bearing on bulk cargo-capacity.

Two general lines of effort here are recognized, each more or less independent of the other, though not completely.

1. Modification of propeller drive from the standard direct coupling of engine crankshaft to propeller;

2. Modifications of engine design from the standard air-injection, four-cycle, single-acting crosshead type.

With regard to the first: There are the two possibilities that have been applied to the turbine, the gear drive and the electric, and the adoption of which in the order stated, has converted the commercially unsuccessful direct-coupled steam turbine into the present success of the indirect, which permits complete independence of engine and propeller speeds. The weight of oil engines per horsepower decreases with decrease of cylinder size,

for the same mean piston speeds, even without any change in the design arrangements and proportions of the parts. The higher rotative speed of the smaller engines is not suitable for direct coupling of propellers, and an indirect connection is necessary before advantage can be taken of this sort of weight reduction. In fact, for such direct-coupled engines as are in successful service the low propeller speed has required long strokes, about 1.6 times the bore, which, with indirect coupling, may be made shorter or more nearly equal to the bore with corresponding advantage, by the increased rotative speed in weight reduction of the same horsepower capacity per cylinder. This situation is almost a direct parallel to that of the direct-coupled steam turbine and points directly toward a similar solution of gear drives or electric drives. Gear driving would be cheaper than electric drive for the same engine, and it permits the operation of a single screw which also saves weight over twin screws, with two engines driving one big gear. The reduction in engine weight for such a combination would not be great, however, not nearly so great as with a greater number of engines, which will permit very material increase of rotative speed, partly because of reduction of horsepower per cylinder but also by reason of shorter strokes. Such engine multiplicity becomes most practical with electric drive, in which case a single propeller shaft carrying a motor located aft, can be electrically connected to any number of high-speed, oil-engine generating sets, preferably D.C., and operating in series. The greater the number of these sets, the higher the speed and the lower the weight per horsepower.

The manœuvering advantage of this combination and its reliability factors, permitting one engine to be overhauled at sea with little loss of speed, have been much discussed and are now well understood. The objections against the plan lie in the very much larger number of cylinders, pistons, valves and other parts to be kept clean and in adjustment, and the fear that higher rotative speeds will mean lessened life. As to the latter point there seems to be no reason to fear lesser life with appropriate design and modern forced feed lubrication of all main running parts. Small parts of the valve gear and control system, subjected to inertia shocks, may so suffer, but these are all light, comparatively cheap, and with a multiplicity of engines can be cared for at sea in a way impossible with direct-coupled large units. There are hundreds of

such engines at work in stationary power plants, giving good service and proving their right to consideration for ship propulsion, exactly as happened with the steam turbogenerator sets now coming into use for steam-turbine electric drive. At sea no better proof of the reliability of high-speed engines can be found, than the performance of the German submarines in the late war, and which engines are now being manufactured by seven different firms in Germany for stationary power-plant service, in some cases superseding the designs developed by these firms, and that were formerly offered by them in competition.

All things considered, it seems proper to accept for the new model of Diesel ship to be compared with the turbine electric drive, the corresponding direct parallel which is the Diesel electric drive, with considerable multiplicity of generating units to get the weight reduction desired, and with electric auxiliaries, but without auxiliary generating sets except for a small engine to be used in port when not handling cargo.

There still remains the question of the engine itself. Here the variety of possibilities is almost infinite, but it is not necessary for the present to go into all of these in detail because we now have available suitable engines for the purpose and as new forms develop, for either direct-coupled service, gear-drive or electric-drive, the value of each will be determined by ordinary engineering analyses and commercial competition. Some of these suggestions are, however, worthy of mention, as bearing on the future possibility of further advances in the oil-engine art, a matter of particular interest in view of the fact that the steam turbine has very nearly reached its limit in the high-speed turbogenerator unit. Some of these items of possibility, development of which will be watched with interest, are:

1. Revival of the two-cycle competition with four-cycle;

2. Double-acting engines, especially two-cycle;

3. Special mechanism arrangements of which Junkers and Fullagar are examples;

4. Higher mean effective pressure rating of all engines over the present standard of 70 lbs. brake, by improved spraying and special combustion chamber arrangements to utilize more of the air charge than the present 50 per cent. approximately. In special cases over 100 lbs. mean-pressure brake have been reached;

5. Higher rating by supercharging with air, starting com-

pression with more than one atmosphere pressure, experimental values of 150 lbs. mean-pressure brake have been secured;

6. Improved construction of cylinder liners, heads and pistons to permit of higher rates of heat generation, and transmission to the jackets in B.T.U. per hour per sq. ft. without injury to the metal and possibly with special construction and special metals. The higher heat generating rates may be due to larger cylinders than now used, to higher speeds, or to increased amounts of oil per cu. ft. combustion chamber obtained by 4 or 5;

7. Elimination of compressed air as a spraying means by development of solid injection;

8. Reduction of metal weight per cu. ft. of cylinder by the more extensive use of steel instead of cast iron;

9. Development of new types of oil engine that do not fall under the Diesel classification, and might be called non-Diesel.

While all of these things are of great engineering interest, as showing further possibilities of development of good oil engines not yet realized, but which may well be expected to extend the commercial importance of the oil engine in the future over whatever proper economic position it has so far earned, it is not, as stated before, necessary to wait upon them, to make a material and useful change in the motorship now.

In considering this proposal for change, it must not be forgotten that the present standard direct-coupled, twin-screw Diesel ship discussed is a real success, and has a definite economic position in competition with the turbine that it will in all probability retain. The point in question is not the abandonment of this successful type of ship, but rather the development of another type of motorship that will have another and different economic position, also useful.

In selecting the Diesel electric drive with multiplicity of engines, as a model for comparison, it must be understood also that there is no implication of fixed superiority over other suggestions. This selection is made merely because it seems to be a promising and useful type with a field of its own, and the logical arrangement is to set up in comparison with the turbine electric drive with Diesel auxiliaries.

The Diesel electric motorship has some steam-turbine electric drive characteristics, the use of high-engine and low-propeller speeds in the interest of low cost and weight of machinery, and

with its advantages of control and manœuvering. To gain these things some fuel is sacrificed because it can be spared.

Similarly, the electric-drive turbine ship has borrowed from the motorship its identical economical auxiliary system to save fuel, but weight and cost are increased, again because there is plenty of margin.

The equipment items of the Diesel electric ship with the weights and estimated costs of each are collected in Table XV.

TABLE XV.

Equipment List for Installation of Single-Screw Diesel Electric Drive, 3500 S. H. P. at 90-100 R. P. M., Motor Aft., with Electric Auxiliaries.

Group	Equipment Item	Weight Tons	Cost Dollars
A	Seven 600-H. P. high-speed D. C. generating sets, 300 R. P. M. complete with exciters, controls, air bottles, valves, silencers	380.00	$ 90,000
B	One 50 K. W. auxiliary oil engine generating set with air compressor	11.00	9,000
C	One 50 K. W. oil engine generating separate exciter set complete	7.00	8,000
D	One donkey boiler, 200 sq. ft. with feed pump and oil burners for heating ship and fuel oil	8.00	1,000
E	Pumps for fresh water, ballast, fuel and lubricating oil, jacket circulating water, bilge, fire and bilge and sanitary uses motor driven, and steam emergency air compressor	20.00	15,000
F	Fixed equipment, additional piping stack and tanks, platforms	30.00	13,000
G	Deck auxiliaries, ten electric winches with windlass and steering gear	60.00	60,000
H	Power transmission, one–3500 H. P. electric motor complete with ventilators, mounting, shafts, bearings and propeller	110.00	95,000
	Total	626.00	$491,000
	Total per H. P.	.179 tons	$140.00

From this table it appears that the machinery weight of the Diesel electric drive is 626 tons, a reduction of 400 tons, or 40 per cent. of the weight for the direct-coupled Diesel, and the cost is $491,000 for the machinery, a reduction of 20 per cent., in spite of the addition of considerable electric equipment. This Diesel electric equipment of generators, motor and control weighs more and costs more than the corresponding turbine equipment because it is of the D.C. instead of A.C. type.

Independent of this electric equipment, the greatest single item of difference of the Diesel electric over the direct-coupled Diesel, is in the engines, which weigh only 150 lbs. per horsepower instead of 400 lbs. more or less. This is the direct result of high speed, 300 R.P.M. against 120 R.P.M., and a corresponding change from the crosshead to truck-piston type similar to the submarine and appropriate to such high-speed engines developing 100 horsepower per cylinder, instead of nearly 300 at the low speed. That such a change does not involve any hazard is proved not only by the success of such engines in stationary service, but also by comparison with the German submarine engine of 1200 horsepower in 6 cylinders at 450 R.P.M., brought to this country, tested and dismantled at the Philadelphia Navy Yard.

The engine is reported to have cylinders $18'' \times 16\frac{1}{2}''$ and gave good service at 450 R.P.M., at which figure the mean piston speed was 1240 feet per minute, a high value. The rated mean-pressure brake is 86 lbs. and the fuel consumption .42 lbs. per hour, per B.H.P. The engine weighs 57,000 lbs., or 47.5 lbs. per horsepower.

On the assumption that cargo service requires more conservative engine ratings, and lowest cost is not consistent with the least possible weight, the same engine might well be operated for commercial work at lower speed, lower rating, and be built with more metal to save shop expense. Reducing the rating mean pressure from 86 lbs. to the present standard of 70 lbs. and reducing speed from 450 R.P.M. to 300 R.P.M., and mean piston speed from over 1200 to about 800, the horsepower would be reduced from 1200 horsepower to 650 horsepower. With no change in metal weight, the engine would then weigh 88 lbs. per horsepower. It is, therefore, clear that the 150 lbs. per horsepower taken is very conservative, being nearly twice the weight of the submarine engine operated at reduced speed, and at standard commercial mean-pressure rating.

The two new electric-drive ships, steam turbine with Diesel electric auxiliaries, and the Diesel, can now be compared with each other as to economy of operation, by finding cargo capacities and yearly freight earnings, disbursements, and by their differences, the investment returns, using the same methods as were used for the present standard ships in Part I.

Cargo-capacities are determined from the dead-weight by subtracting the total of supplies of stores, water and fuel, which are based on the rates of consumption of the two ships per Table XVI.

TABLE XVI.

Consumption Rates of Consumable Supplies (Long Tons).

Item	Per Day At Sea		Per Day in Port	
	Steamship (Electric)	Motorship (Electric)	Steamship (Electric)	Motorship (Electric)
Stores	1.00	1.00	1.00	1.00
Water	13.00	3.00	3.00	3.00
Fuel	35.60	20.60	12 tons per call	12 tons per call

These rates are based on the assumption that stores and water consumption will be the same for the electric-drive ships as for

TABLE XVII.

Consumable Supplies, Tons per Return Voyage.

Days, Single voyage		Stores		Water		Fuel		Total		Total Weight + Reserve	
Sea	Lay	Out	In	Out	In	Out	In	Out	In	Out	In
STEAMSHIP (ELECTRIC)											
5	20	50	25	125	125	178	178	353	328	388	361
10	20	60	30	190	190	356	356	606	576	667	634
20	20	80	40	320	320	712	712	1112	1072	1223	1179
30	20	100	50	450	450	1068	1068	1618	1568	1780	1725
40	20	120	60	580	580	1424	1424	2124	2064	2336	2270
50	20	140	70	710	710	1780	1780	2630	2560	2893	2816
60	20	160	80	840	740	2136	2136	3136	3056	3450	3362
MOTORSHIP (ELECTRIC)											
5	20	50	25	75	75	103	103	228	203	251	223
10	20	60	30	90	90	206	206	356	326	392	359
20	20	80	40	120	120	412	412	612	572	673	629
30	20	100	50	150	150	618	618	868	818	955	900
40	20	120	60	180	180	824	824	1124	1064	1236	1170
50	20	140	70	210	210	1030	1030	1380	1310	1518	1441
60	20	160	80	240	240	1236	1236	1636	1556	1800	1712

the others, the only changes being in the fuel consumption, which for the turbine electric is lower than for the gear drive, and for the Diesel electric higher than for the Diesel direct-coupled.

From the consumption rates of Table XVI, the yearly totals of consumable supplies are determined for the same voyage lengths used before, and reported with 10 per cent. reserves in Table XVII.

The cargo-capacity in tons per voyage and in ton-miles per year are worked out and reported in Table XVIII and Table XIX, respectively, the last one giving also the yearly freight earnings. To show more clearly how these items compare for the two types

TABLE XVIII.

Dead-Weight Distribution (Long Tons).

(Average Single Voyage)

Sea Days	Stores	Water	Stores Water	Fuel	Stores Water Fuel	Total Reserve	Cargo 10,000 − (Total + Reserve)
			STEAMSHIP (ELECTRIC)				
5	38	125	163	178	340	374	9626
10	45	190	235	356	591	650	9350
20	60	320	380	712	1092	1200	8800
30	75	450	525	1068	1593	1750	8250
40	90	580	670	1424	2094	2300	7700
50	105	710	815	1780	2595	2855	7145
60	120	840	960	2136	3096	3405	6595
			MOTORSHIP (ELECTRIC)				
5	38	75	113	103	215	236	9764
10	45	90	135	206	341	375	9625
20	60	120	180	412	592	650	9350
30	75	150	225	618	843	927	9073
40	90	180	270	824	1094	1205	8795
50	105	210	315	1030	1345	1480	8520
60	120	240	360	1236	1596	1755	8245

of ships, the results are plotted in curve form in Figs. 11, 12 and 13, which are comparable with Figs. 1, 2 and 3 for the two ships without electric drives.

Disbursements for the electric-drive ship are very difficult to estimate not only for the reasons that apply to everything else, uncertain wages, rates and prices, but particularly because of lack of experience with these new ships the quantities involved are not established. About the only course open is to assume that such items as maintenance, crew wages and subsistence, loss and dam-

TABLE XIX.

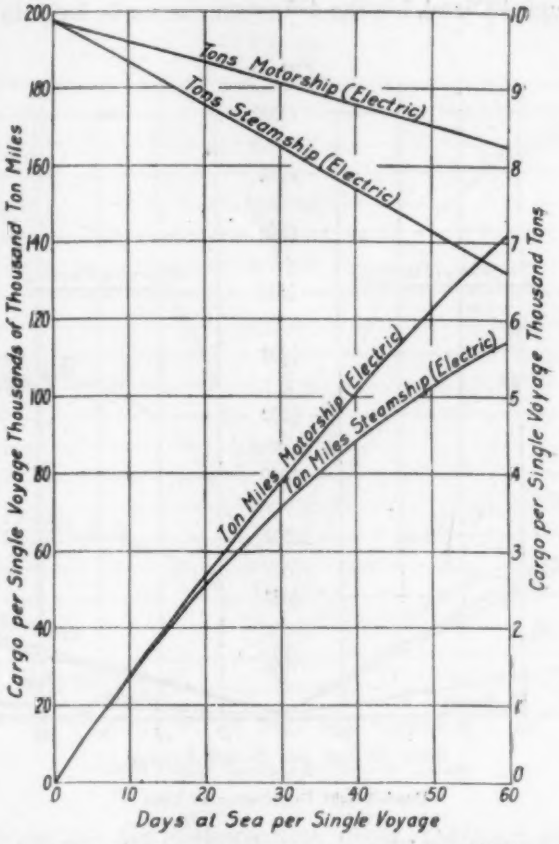
Cargo (D. W.) Capacity and Yearly Gross Freight Earnings.

STEAMSHIP (ELECTRIC)

Days per single voyage		D.W. per single voyage		Distance, miles	Ton-miles cargo per single voyage	Single voyage per year 350 days	Thousand ton-miles per year	Gross earnings at freight rates per 1000 ton-miles of		
Sea	Lay	Supply	Cargo					$1.00	$2.00	$3.00
5	20	374	9626	1,440	13,850	14.00	194,000	194,000	388,000	582,000
10	20	650	9350	2,880	26,900	11.65	313,000	313,000	626,000	939,000
20	20	1200	8800	5,760	50,700	8.75	443,000	443,000	886,000	1,329 000
30	20	1750	8250	8,640	71,250	7.00	498,000	498,000	996,000	1,494,000
40	20	2300	7700	11,520	88,700	5.84	517,000	517,000	1,034,000	1,551,000
50	20	2855	7145	14,400	102,800	5.00	514,000	514,000	1,028,000	1,542,000
60	20	3405	6595	17,280	113,800	4.38	498,000	498,000	996,000	1,494,000
MOTORSHIP (ELECTRIC)										
5	20	236	9764	1,440	14,050	14.00	197,000	197,000	394,000	591,000
10	20	375	9625	2,880	27,700	11.65	323,000	323,000	646,000	969,000
20	20	650	9350	5,760	53,800	8.75	471,000	471,000	942,000	1,413,000
30	20	927	9073	8,640	78,400	7.00	548,000	548,000	1,096,000	1,644,000
40	20	1205	8795	11,520	101,000	5.84	590,000	590,000	1,180,000	1,770,000
50	20	1480	8520	11,400	122,600	5.00	613,000	613,000	1,226,000	1,839,000
60	20	1755	8245	17,280	142,300	4.38	623,000	623,000	1,246,000	1,869,000

age, stores and port charges will be the same for the electric-drive as for the non-electric-drive ships of the two types, and then having determined the yearly returns, see if the differences are of such

FIG. 11.

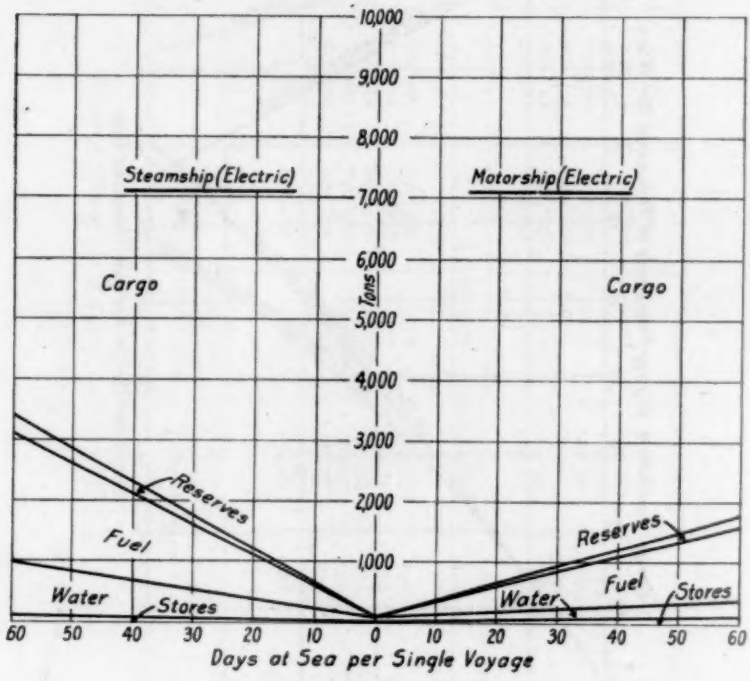


Cargo-Capacity per Single Voyage Tons and Ton-Miles.

an order of magnitude as might change conclusions should the items assumed equal, be not so within a possible range. This is equivalent to saying that if the yearly returns of the two types of ship are so close that the balance will be thrown one way or the other, solely on maintenance and crew expenses, they are really competitive and attention can then be concentrated on these items

As a matter of fact, it is found that the economic zoning of the operating field of the two types is so definite as to be not seriously disturbed by any reasonable changes here. It is likely that crew expense will be greater for both electric-drive ships, and that maintenance of the Diesel electric will be greater than for the direct-coupled Diesel, but the difference cannot be large in its effect

FIG. 12.



Dead-Weight Distribution in Tons.

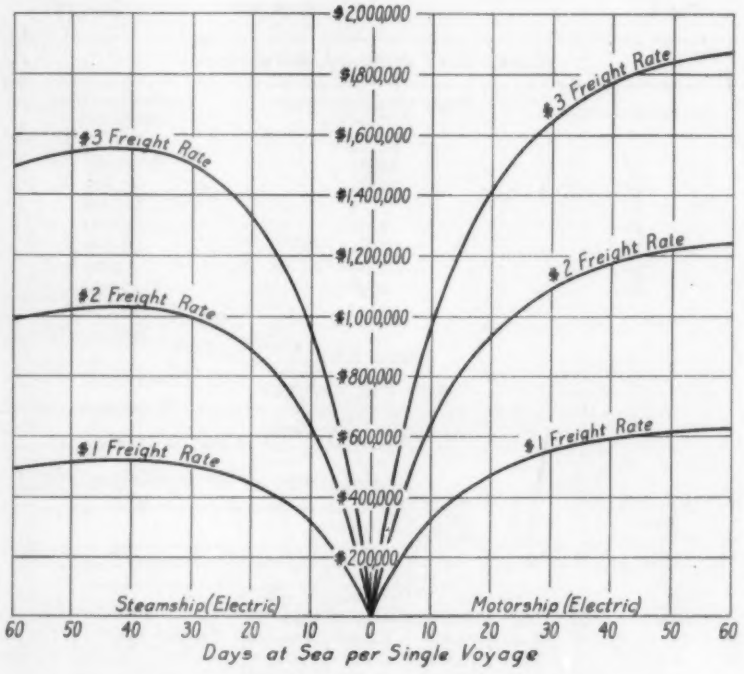
on yearly returns, and in any case is necessarily offset by greater reliability of drive and facility of manœuvering, which assurance against breakdown, collision or delay, may well be regarded as worth something.

Disbursements for insurance and fuel are different. That for insurance is in proportion to the new first costs, 5 per cent. on which produces the charge of $67,250 and $73,300 per year against the turbine and Diesel electrics, respectively.

These annual disbursements, exclusive of fuel, are collected in Table XX.

Disbursements for fuel are in proportion to consumption and to the price per barrel, and are collected in Table XXI for fuel prices from $1 to $5 per barrel.

FIG. 13.



Gross Freight Earnings per Year in Dollars.

Collecting all the disbursement items, the total annual expenses are given in Table XXII, and plotted in Fig. 14 for the electric-drive ships, which is comparable with Fig. 4 for the non-electric. It is clear from such a comparison that expenses for the Diesel electric are higher than for the direct-coupled, and for the turbine electric lower than for the geared turbine. The totals are closer together than before, as was also the case for freight earnings, and for first costs, too.

TABLE XX.

Fixed Annual Disbursements.

Item	Steamship (Electric)	Motorship (Electric)
Maintenance	$ 32,000	$ 32,000
Crew wages and subsistence	73,300	73,300
Loss and damage	3,650	3,650
Stores	21,900	21,900
Insurance	67,250	73,300
Total	$198,100	$204,150

YEARLY PORT CHARGES, BOTH SHIPS

Day per single voyage	Single voyages per year port calls	Yearly port charges approximate
5	14.00	$112,000
10	11.65	93,200
20	8.75	70,000
30	7.00	56,000
40	5 84	46,700
50	5.00	40,000
60	4.38	35,040

TABLE XXI.

Annual Fuel Expense.

STEAMSHIP (ELECTRIC)

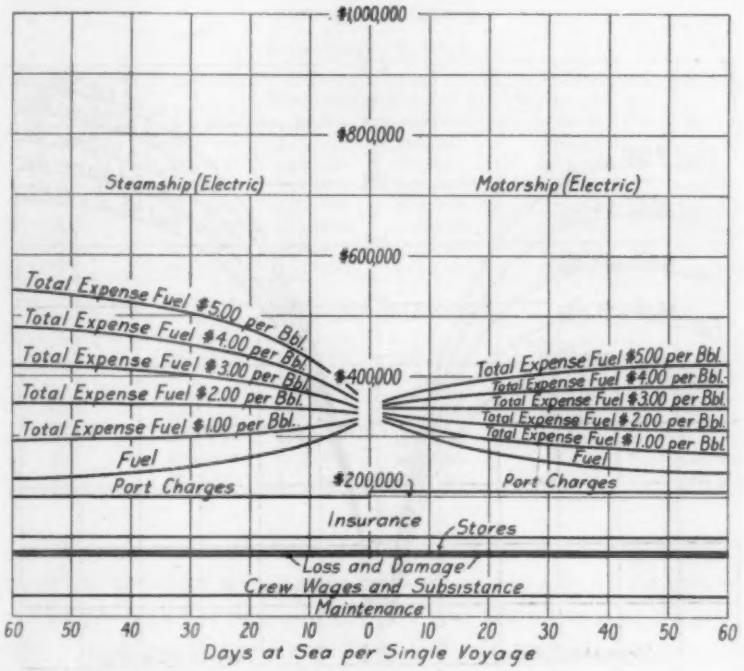
Days per single voyage	Single voyages per year	Fuel tons per single voyage	Fuel tons per year	Fuel bbls. per year	Fuel expense per year at dollars per bbl. of 1	2	3	4	5
5	14.00	178	2490	16,500	$16,500	$ 33,000	$ 49,500	$ 66,000	$ 82,500
10	11.65	356	4140	27,400	27,400	54,800	82,200	109,600	137,000
20	8.75	712	6225	41,200	41,200	82,400	123,600	164,800	206,000
30	7.00	1068	7480	49,500	49,500	99,000	148,500	198,000	247,500
40	5.84	1424	8320	55,100	55,100	110,200	165,300	220,400	275,500
50	5.00	1780	8900	58,900	58,900	117,800	176,700	235,600	294,500
60	4.38	2136	9350	61,900	61,900	123,800	185,700	247,600	309,500

MOTORSHIP (ELECTRIC)

5	14.00	103	1445	9,570	$ 9,570	$19,140	$ 28,710	$ 38,280	$ 47,850
10	11.65	206	2400	15,900	15,900	31,800	47,700	63,600	79,500
20	8.75	412	3610	23,900	23,900	47,800	71,700	95,600	119,500
30	7.00	618	4330	28,700	28,700	57,400	86,100	114,800	143,500
40	5.84	824	4810	31,900	31,900	63,800	95,700	127,600	159,500
50	5.00	1030	5150	34,100	34,100	68,200	102,300	136,400	170,500
60	4.38	1236	5420	35,900	35,900	71,800	107,700	143,600	179,500

Just how these three consistent related charges will affect the respective earnings of the two types of electric-drive ship is not clear without detailed figures on the per cent. returns for each combination of the three freight rates, $1, $2 and $3 per 1000 ton-miles, with the five fuel oil prices of $1, $2, $3, $4 and $5 per barrel.

FIG. 14.



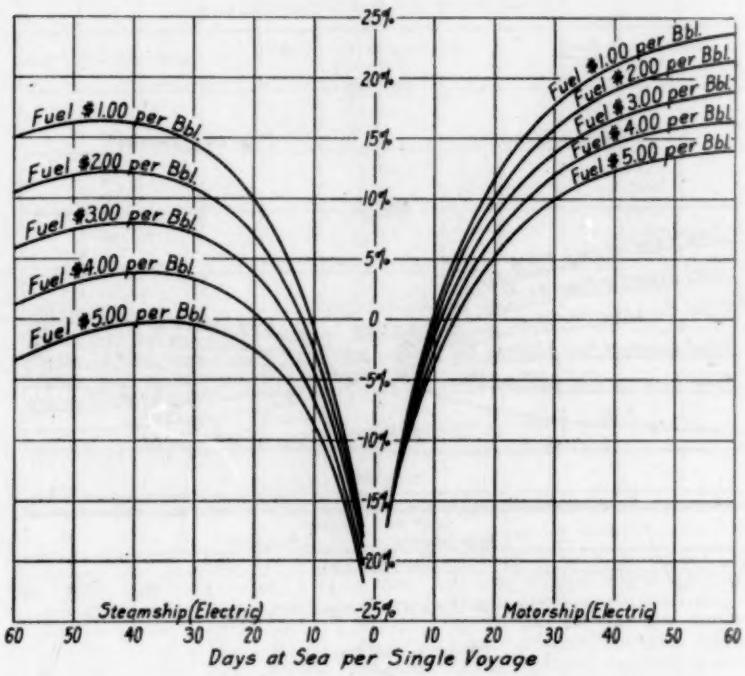
Total Annual Expense.

These per cent. returns are collected in Table XXIII (A, B, and C) for the three freight rates, respectively, and plotted in Figs. 15, 16, and 17. These curves of per cent. returns for the two electric-drive ships are directly comparable with the corresponding curves, Figs. 5, 6, and 7, for the non-electric, which are very similar in relation, and, of course, identical in form.

While these figures fix the relative economic positions of the two types of electric-drive ship, it is not easy to see at a glance

the effect of freight rates and fuel oil prices. To assist in this, the per cent. returns on the investment for every condition computed, are collected and arranged in Table XXIV, which is directly comparable with Table XIII for the non-electric ships. The per cent. returns on the investment represents the undistributed yearly excess of freight income (or deficit) over disbursements, divided

FIG. 15.



Annual Return on Investment with Freight Rate of $1.00 per 1000 Ton-Miles.

by the investment cost of the ship, from which profit and loss is to be determined after providing for book reserves.

To make clear just how the returns for one ship compare with another for any one condition, the curves are replotted with turbine and Diesel curves superimposed in Figs. 18, 19 and 20 for freight rates of $1, $2 and $3.

These figures show that long voyages, high fuel prices and low freight rates favor the motorship which always has a clear non-competitive field in the longer voyages, and when voyages are short, it is more or less equal to or competitive with the steamer per 1000 ton-miles, respectively.

TABLE XXII.

Total Annual Expense.

STEAMSHIP (ELECTRIC)

Days per single voyage	Total expense with fuel in dollars per bbl. at				
	$1.00	$2.00	$3.00	$4.00	$5.00
5	327,000	343,000	360,000	376,000	393,000
10	319,000	346,000	373,000	401,000	428,000
20	309,000	350,000	392,000	433,000	474,000
30	304,000	353,000	403,000	452,000	502,000
40	300,000	355,000	410,000	465,000	520,000
50	297,000	356,000	415,000	474,000	533,000
60	295,000	357,000	419,000	481,000	543,000

MOTORSHIP (ELECTRIC)

5	326,000	336,000	345,000	355,000	365,000
10	313,000	330,000	345,000	361,000	377,000
20	299,000	322,000	346,000	370,000	394,000
30	289,000	318,000	347,000	375,000	404,000
40	283,000	315,000	347,000	379,000	411,000
50	279,000	313,000	347,000	381,000	415,000
60	275,000	311,000	347,000	383,000	419,000

Where a curve of one ship crosses the corresponding curve for the other, the ships are equal in returns; on one side of the crossing one ship is superior and on the other side the other is more profitable. In this way the competitive and non-competitive zones are pretty clearly defined.

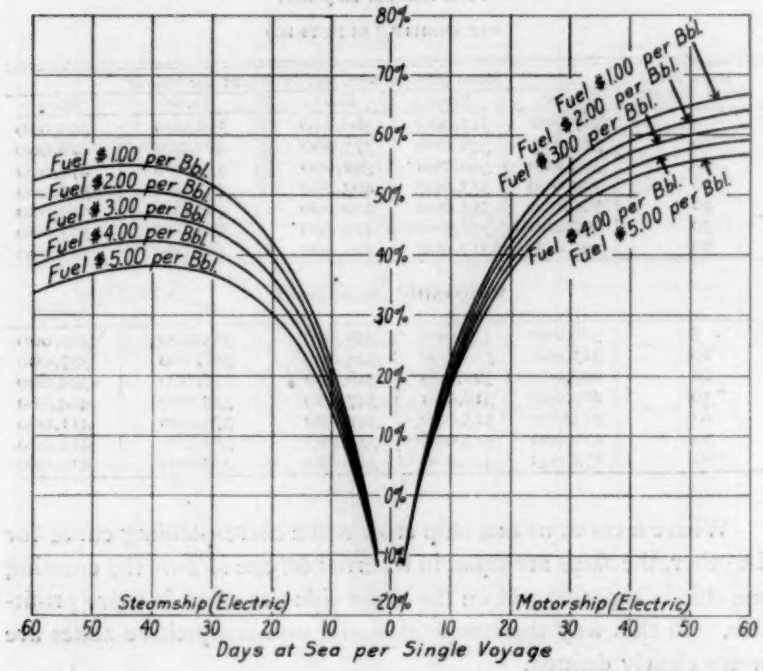
Inspection of these curves and the figures of the last table enable the following conclusions to be drawn with regard to these economic zones in terms of length of voyage, freight rate and fuel price.

Starting with a fuel price of $3 per bbl. and a freight rate of $1 per 1000 ton-miles, both ships show a loss for voyages of less than 10 days. The motorship consistently yields better returns for longer voyages: 8.5 per cent. *vs.* 3.7 per cent. for 20 days, 13.7 per cent. *vs.* 7 per cent. for 30 days, 16.6 per cent. *vs.* 8 per

cent. for 40 days, 18 per cent. *vs.* 17.4 per cent. for 50 days, 18.8 per cent. *vs.* 5.9 per cent. for 60 days.

For the $2 freight rate, neither ship shows a loss, but the Diesel is better over the whole range, the figures being, 3.3 per cent. *vs.* 2 per cent. for 5 days, 20.5 per cent. *vs.* 18.8 per cent. for 10 days, 40.4 per cent. *vs.* 36.7 per cent. for 20 days, 51 per cent.

FIG. 16.



Annual Return on Investment with Freight Rate of $2.00 per 1000 Ton-Miles.

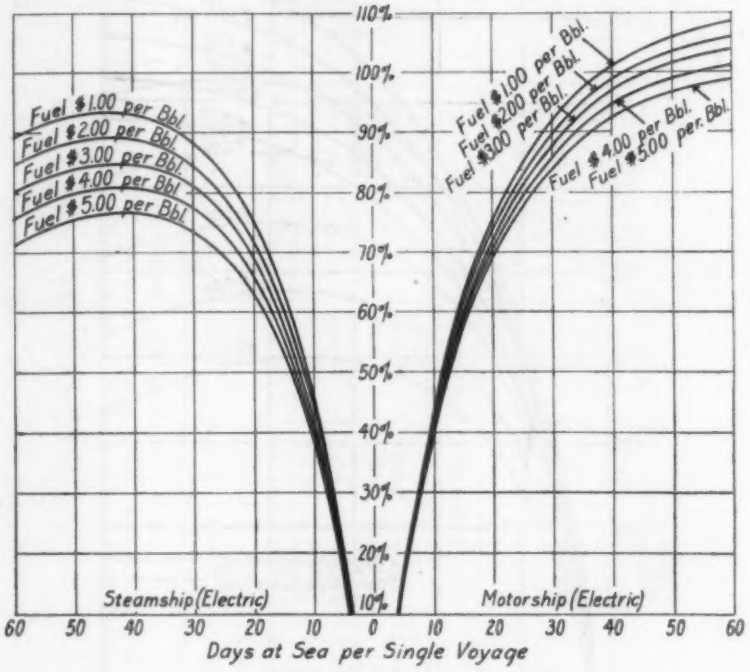
vs. 44 per cent. for 30 days, 56.8 per cent. *vs.* 46.3 per cent. for 40 days, 52.8 per cent. *vs.* 45.6 per cent. for 50 days, and 61.2 per cent. *vs.* 43 per cent. for 60 days, the difference increasing faster after 20 days.

For a $3 freight rate, the two ships are competitive on about an equal earning basis for voyages up to about 20 days, after which the motorship earnings increase faster, being 88.4 per cent. *vs.* 81.2 per cent. for 30 days, 97.2 per cent. *vs.* 85 per cent. for

40 days, 102 per cent. *vs.* 84 per cent. for 50 days, and 104 per cent. *vs.* 80 per cent. for 60 days.

At a higher fuel price of $4 per bbl., and with a $1 freight rate, both ships show a loss up to 10 days, after which the motorship is uniformly better. The figures are 6.9 per cent. *vs.* 0.7 per

FIG. 17.



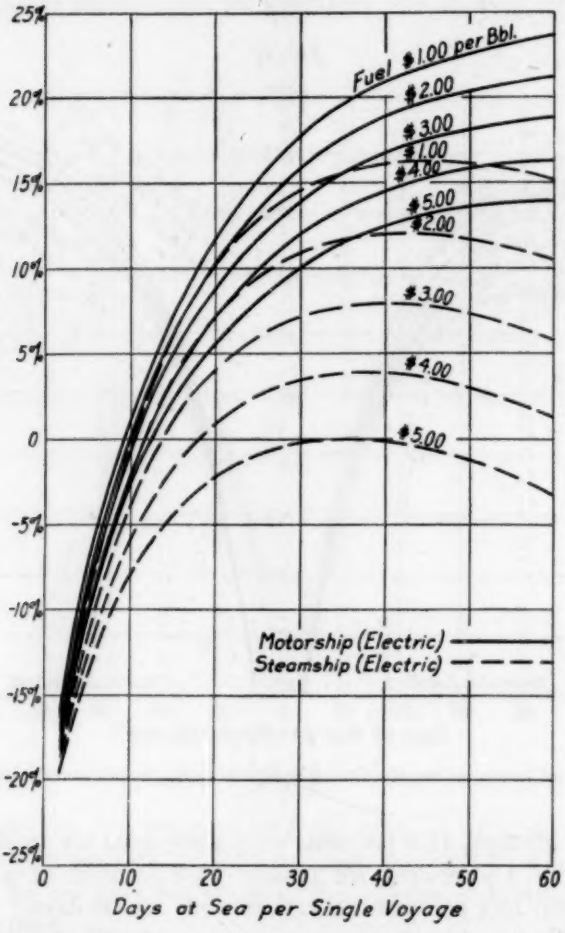
Annual Return on Investment with Freight Rate of $3.00 per 1000 Ton-Miles.

cent. for 20 days, 11.8 per cent. *vs.* 3.4 per cent. for 30 days, 14.4 per cent. *vs.* 3.9 per cent. for 40 days, 15.8 per cent. *vs.* 3 per cent. for 50, and 16.4 per cent. *vs.* 1.3 per cent. for 60 days.

At a $2 freight rate, there is no loss, and both ships are about equal up to 20 days, the motorship gaining beyond this. The returns are 49.1 per cent. *vs.* 40.4 per cent. for 30 days, 54.3 per cent. *vs.* 42.3 per cent. for 40 days, 57.5 per cent. *vs.* 41.2 per cent. for 50 days, and 58.8 per cent. *vs.* 38.3 per cent. for 60 days.

For a $3 freight rate, the ships are about equal for voyages for 10 days, after which the motorship *vs.* turbine figures are 71.3 per cent. *vs.* 66.6 per cent. for 20 days, 86.5 per cent. *vs.* 77.5 per

FIG. 18.



Annual Return on Investment with Freight Rate of $1.00 per 1000 Ton-Miles.

cent. for 40 days, 95 per cent. *vs.* 80.8 per cent. for 40 days, 99.5 per cent. *vs.* 79.3 per cent. for 50 days, and 101 per cent. *vs.* 75 per cent. for 60 days.

TABLE XXIII (A).

Annual Return on Investment. Undistributed Excess or Deficit. Freight Rates of $1.00 Per 1000 Ton-Miles

STEAMSHIP (ELECTRIC) $1,345,000

Days per single voyage	Fuel at $1 per bbl.		Fuel at $2 per bbl.		Fuel at $3 per bbl.		Fuel at $4 per bbl.		Fuel at $5 per bbl.	
	Dollars	%	Dollars	%	Dollars	%	Dollars	%	Dollars	%
5	−133,000	− 9.90	−149,000	−11 08	−166,000	−12.33	−182,000	−13.52	−199,000	−14.80
10	− 60,000	− .55	− 33,000	− 2.53	− 60,000	− 4.46	− 88,000	− 6.55	−115,000	− 8.55
20	134,000	9.96	93,000	6.91	50,000	3.72	10,000	.74	− 31,000	− 2.30
30	194,000	14.42	145,000	10.78	95,000	7.06	46,000	3.42	− 4,000	− .30
40	217,000	16.13	162,000	12.04	107,000	7.96	52,000	3.87	− 3,000	− .22
50	217,000	16.13	158,000	11.75	99,000	7.35	40,000	2.98	− 19,000	− 1 41
60	203,000	15.10	141,000	10.50	79,000	5.87	17,000	1.26	− 45,000	− 3.35

MOTORSHIP (ELECTRIC) $1,466,000

5	−129,000	− 8.80	−139,000	− 9.48	−148,000	−10.10	−158,000	−10.78	−168,000	−11.45
10	10,000	.68	− 7,000	− .48	− 22,000	− 1.50	− 38,000	− 2.59	− 54,000	− 3.68
20	172,000	11.72	149,000	10.17	125,000	8.53	101,000	6.89	77,000	5.25
30	259,000	17.66	230,000	15.69	201,000	13.70	173,000	11.80	144,000	9.83
40	307,000	20.92	275,000	18.75	243,000	16.57	211,000	14.39	179,000	12.21
50	334,000	22.79	300,000	20.45	266,000	18.13	232,000	15.82	198,000	13.50
60	348,000	23.71	312,000	21.27	276,000	18.80	240,000	16.37	204,000	13.91

TABLE XXIII (B).

Annual Return on Investment. Undistributed Excess or Deficit Freight Rate of $2 00 per 1000 Ton-Miles.

Days per single voyage	Fuel at $1 per bbl.		Fuel at $2 per bbl.		Fuel at $3 per bbl.		Fuel at $4 per bbl.		Fuel at $5 per bbl.	
	Dollars	%	Dollars	%	Dollars	%	Dollars	%	Dollars	%
STEAMSHIP (ELECTRIC) $1,345,000										
5	61,000	4.53	45,000	3.34	28,000	2.08	12,000	.89	– 5,000	– .37
10	307,000	22 80	280,000	20.80	253,000	18.80	225,000	16.72	198,000	14.72
20	577,000	42.80	536,000	39.85	494,000	36.70	453,000	33.70	412,000	30.60
30	692,000	51.40	643,000	47.80	593,000	44.10	544,000	40.40	494,000	36.80
40	734,000	54.50	679,000	50.40	624,000	46.30	569,000	42.30	514,000	38.20
50	731,000	54.30	672,000	49.90	613,000	45.60	554,000	41.20	495,000	36.80
60	701,000	52.20	639,000	47 50	577,000	42.90	515,000	38.30	453,000	33.70
MOTORSHIP (ELECTRIC) $1,466,000										
5	68,000	4.64	58,000	3.95	49,000	3.34	39,000	2.66	29,000	1.98
10	333,000	22.70	316,000	21.30	301,000	20.50	285,000	19.40	269,000	18.30
20	643,000	43.80	620,000	42.00	596,000	40.40	572,000	39.00	548,000	37.30
30	807,000	55.00	778,000	53.00	749,000	51.00	721,000	49.10	692,000	47.20
40	897,000	61.10	865,000	58.70	833,000	56.75	801,000	54.30	769,000	52.30
50	947,000	64.50	913,000	62.00	879,000	59.80	845,000	57.50	811,000	55.30
60	971,000	66.20	935,000	63.70	899,000	61.20	863,000	58.80	827,000	56.40

TABLE XXIII (C).

Annual Return on Investment. Undistributed Excess or Deficit. Freight Rate of $3.00 per 1000 Ton-miles.

STEAMSHIP (ELECTRIC) $1,345,000

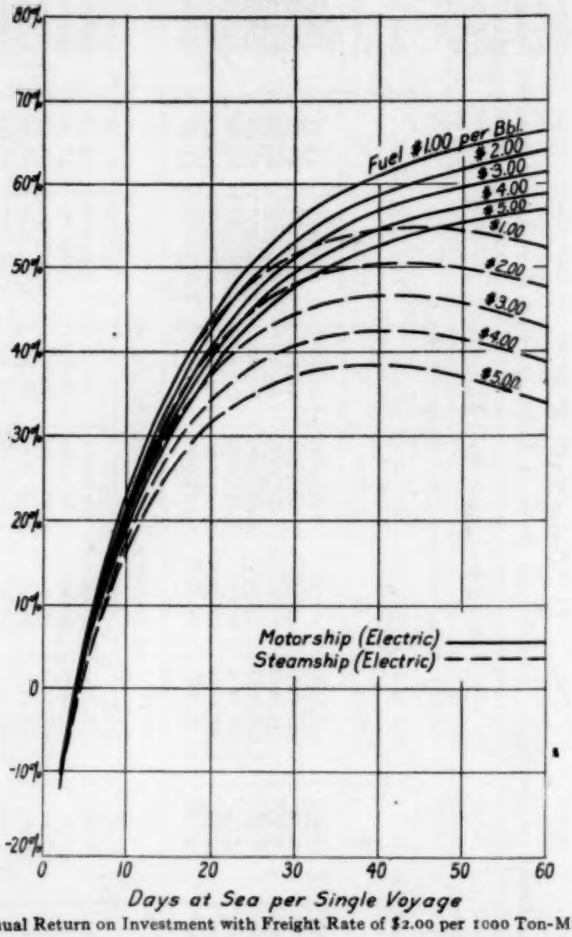
Days per single voyage	Excess income over disbursements or deficit									
	Fuel at $1 per bbl.		Fuel at $2 per bbl.		Fuel at $3 per bbl.		Fuel at $4 per bbl.		Fuel at $5 per bbl.	
	Dollars	%	Dollars	%	Dollars	%	Dollars	%	Dollars	%
5	255,000	18.95	239,000	17.76	222,000	16.50	206,000	15.31	189,000	14.05
10	620,000	46.10	593,000	44.05	566,000	42.10	538,000	40.00	511,000	38.00
20	1,020,000	75.90	979,000	72.70	937,000	69.60	896,000	66.60	855,000	63.60
30	1,190,000	88 50	1,141,000	84.90	1,091,000	81.20	1,042,000	77.50	992,000	73.70
40	1,251,000	93.00	1,196,000	88.90	1,141,000	84.90	1,086,000	80.80	1,031,000	76.70
50	1,245,000	92.60	1,188,000	88.30	1,127,000	83.80	1,068,000	79.30	1,009,000	75.00
60	1,199,000	89.10	1,137,000	84.50	1,075,000	79.90	1,013,000	75.40	951,000	70.70

MOTORSHIP (ELECTRIC) $1,466,000

5										
10	265,000	18.08	255,000	17.40	246,000	16.78	236,000	16.10	226,000	15.41
20	656,000	44.70	639,000	43.50	624,000	42.50	608,000	41.50	592,000	40.40
30	1,114,000	76.10	1,091,000	74.50	1,067,000	72.75	1,043,000	71.30	1,019,000	69.50
40	1,355,000	92.50	1,326,000	90.50	1,297,000	88.40	1,269,000	86.50	1,240,000	84.60
50	1,487,000	101.40	1,455,000	99.30	1,423,000	97 20	1,391,000	95.00	1,359,000	92.70
60	1,560,000	106.30	1,525,000	104.00	1,492,000	101.90	1,458,000	99.50	1,424,000	97.20
	1,594,000	108.90	1,558,000	106.20	1,522,000	104.00	1,486,000	101.30	1,450,000	99.00

At the maximum fuel price of $5 per barrel, and with a $1 freight rate, the turbine ship shows a deficit over the whole range and the motorship for voyages under 20 days. Beyond this the

FIG. 19.



Annual Return on Investment with Freight Rate of $2.00 per 1000 Ton-Miles.

motorship returns are 9.8 per cent. for 30 days, 12.2 per cent. for 40 days, 13.5 per cent. for 50 days, and 13.9 per cent. for 60 days.

At $2 freight rate, the turbine ship loses under 5 days, but the motorship does not. The comparative figures for motorship *vs.* steamer are 18.3 per cent. *vs.* 14.7 per cent. for 10 days, 37.3 per cent. *vs.* 30.6 per cent. for 20 days, 47.2 per cent. *vs.* 36.8 per cent.

TABLE XXIV.

Per cent. Investment Return Compared

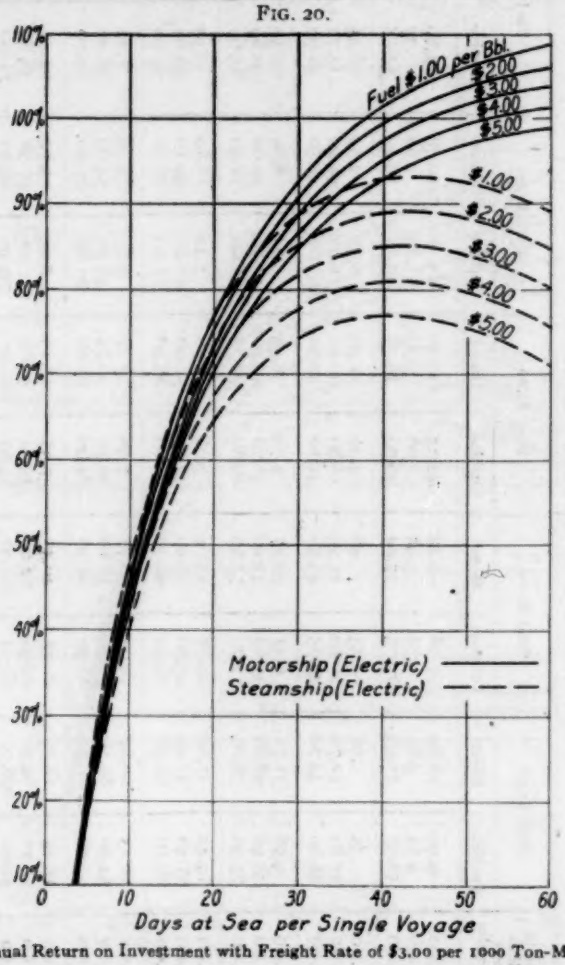
For

(a) Turbine (electric), single screw, Diesel auxiliaries
(b) Diesel (electric), single screw, Diesel auxiliaries

Days per single voyage	Freight dollars 1000 ton-miles	Fuel $1.00		Fuel $2.00		Fuel $3.00		Fuel $4.00		Fuel $5.00	
		Turbine	Diesel	Turbine	Diesel	Turbine	Diesel	Turbine	Diesel	Turbine	Diesel
5	$1.00	-9.90	-8.80	-11.08	-9.48	-12.33	-10.10	-13.52	-10.78	-14.80	-11.45
	2.00	4.53	4.64	3.34	3.95	2.08	3.34	.89	2.66	- .37	1.98
	3.00	18.95	18.08	17.76	17.40	16.50	16.78	15.31	16.10	14.05	15.41
10	1.00	- .55	.68	-2.53	- .48	-4.46	-1.50	-6.55	-2.59	-8.55	-3.68
	2.00	22.80	22.70	20.80	21.30	18.80	20.50	16.72	19.40	14.72	18.30
	3.00	46.10	44.70	44.05	43.50	42.10	42.50	40.00	41.50	38 00	40.40
20	1.00	9.96	11.72	6.91	10.17	3.72	8.53	.74	6.89	-2.30	-5.25
	2.00	48.90	48.80	39.85	42.00	36.70	40.40	37.70	39.00	30.60	37.30
	3.00	75.90	76.10	72.70	74.50	69.60	72.75	66.60	71.30	63.60	69.50
30	1.00	14.42	17.66	10.78	15.69	7.06	13.70	3.42	11.80	-.30	9.83
	2.00	51.40	55.00	47.80	53.00	44.10	51.00	40 40	49.10	36.80	47.20
	3.00	88.50	92.50	84.90	90.50	81.20	88.40	77.50	86.50	73.70	84.60
40	1.00	16.13	20.92	12.04	18.75	7 96	16 57	3 87	14.39	-.22	12.21
	2.00	54.50	61.10	50.40	58.70	46.30	56.75	42 30	54.30	38.20	52.30
	3.00	93.00	101.40	88.90	99.30	84.90	97.20	80 80	95.00	76.70	92.70
50	1.00	16.13	22.79	11.75	20.45	7.35	18.13	2.98	15.82	-1.40	13.50
	2.00	54.30	64.50	49.90	62.00	45.60	59.80	41.20	57.50	36.80	55 30
	3.00	92.60	106.30	88.30	104.00	83.80	101.90	79.30	99.50	75.00	97.20
60	1.00	15.10	23.71	10.50	21.27	5.87	18.82	1.26	16.37	-3.35	13.91
	2.00	52.20	66.20	47.50	63.70	42.90	61.20	38.30	58.80	33.70	56.40
	3.00	89.10	108.90	84.50	106.20	79.90	104.00	75.40	101.30	70.70	99.00

for 30 days, 52.3 per cent. *vs.* 38.2 per cent. for 40 days, 55.3 per cent. *vs.* 36.8 per cent. for 50 days, and 56.4 per cent. *vs.* 33.7 per cent. for 60 days.

FIG. 20.



Annual Return on Investment with Freight Rate of $3.00 per 1000 Ton-Miles.

At the maximum freight rate of $3 the motorship leads a little at first and then regularly by larger margins for longer voyages. The figures are 15.4 per cent. *vs.* 14 per cent. for 5 days, 40.4 per cent. *vs.* 38 per cent. for 10 days, 69.5 per cent. *vs.* 63.6 per cent. for 20 days, 84.6 per cent. *vs.* 73.7 per cent. for 30 days, 92.7 per cent. *vs.* 76.7 per cent. for 40 days, 97.2 per cent. *vs.* 75 per cent. for 50 days, and 99 per cent. *vs.* 70.7 per cent. for 60 days.

Comparing the electric-drive ships with the non-electric, it is evident that the electrification of both ships favors the motorship more than it does the turbine steamer, and reduces the voyage length at which the motorship emerges from the competitive field into its zone of no competition.

TABLE XXV.

Relation of Other Ships to the Geared Turbine Equipment with Steam Auxiliaries.

Item	Geared Turbine Steam Auxiliaries	Twin Diesel Direct Diesel Electric Auxiliaries	Electric Drive	
			Turbine Diesel Elec. Auxil.	Diesel
Weight of machinery	1.00	1.615	1.043	.99
Cost of machinery	1.00	2.11	1.348	1.785
Cost of ship	1.00	1.245	1.075	1.175
Cargo-capacity for 5 day voyage	1.00	.99	1.015	1.03
Cargo-capacity for 60 day voyage	1.00	1.358	1.11	1.39
Fuel consumption per day at sea	1.00	.395	.81	.468
Total yearly expense with fuel $1.00 per barrel and 5 day voyage	1.00	.987	.987	.976
Total yearly expense with fuel $1.00 per barrel and 60 day voyage	1.00	.894	.961	.896
Total yearly expense with fuel $5.00 per barrel and 5 day voyage	1.00	.815	.875	.813
Total yearly expense with fuel $5.00 per barrel and 60 day voyage	1.00	.635	.871	.672

At this point it is worth while to summarize the relation between the various items of equipment, cargo-capacity and disbursements for each of the four types of ships studied, and which are primarily responsible for the conclusions drawn as to economic zoning. For this purpose the figures for the geared turbine ship with steam auxiliaries are taken as unity, so all other figures represent a ratio of the figure for the other ship to that for the geared turbine. These ratios are collected in Table XXV.

Finally, it must be noted that while the conclusions drawn are pretty clear for the large freight vessel of 10,000 D.W.T., and limit the competitive turbine ship to the short-voyage zone, shorter for electric than for non-electric, with a clear field of superiority for long voyages, this short-voyage, competitive zone might well be better served by smaller ships. The smaller vessel of half the dead-weight capacity need remain in port for only half the time so far as cargo handling is concerned and, therefore, neglecting useless waiting time, it has the same ratio of sea time per year as the larger ship, when its voyages are half as long.

As smaller ships are better adapted for short voyages, it seems clear that the short-voyage condition for the larger ship should hardly be considered seriously except to bring out its limitations, and the better adaptability of the smaller ship.

Smaller ships require smaller horsepower and as horsepower per installation is lessened, the steam equipment becomes less adaptable than the oil engine in proportion, both in the direct-coupled units and with the electric drive. As size is reduced, the Diesel electric drive permits the use of the identical engine used for the larger ships but in lesser numbers and adoption of such engines would permit the use of manufacturing methods in their production, not possible when a large number of sizes of big low-speed engines are demanded for direct propulsion, a condition nearly identical with that of the German submarine engine though for different primary reasons. In this reduction of size of installation with identical engines of lesser number, a point will be reached where there are only two, or perhaps one, again bringing forward the geared or direct-coupled possibility, on the one hand, or a smaller engine of still higher speed and lesser weight to be used in larger multiples, on the other hand.

In conclusion, it can be said that the Diesel engine has a definite and useful zone of operation at sea with both the large direct-coupled forms now in use, but also with smaller sizes of higher speed used in multiple with universal application to a wide range of ship sizes and speeds by indirect drive. The former will undoubtedly remain in use, as there is no good reason in sight for retiring it, and if fuel prices rise, as would be natural, and freight rates fall, its position is further strengthened for long-voyage service. The high-speed engine used in multiples seems equally justified, and may well be adopted for immediate use in vessels intended for shorter voyages, vessels of both large and small size, and both for conversion of existing obsolete steamers, as well as for new construction. The use of Diesel machinery must, on economic grounds, definitely increase, and from this conclusion there is no alternative, but a proportionate decrease in steam-turbine machinery for cargo ships. The only clear non-competitive fields that the steam-turbine ship can claim for its own are, first, that in which coal is burned, and second, that of the very large or fast ships requiring more power than can be obtained by oil engines, and especially when speed is worth anything it might cost.

THE BIFILAR WINDBALANCE.*

By A. F. Zahm, Ph.D.

Bureau of Construction and Repair U.S.N.

Preface.—For the delicate measurement of air resistance along stream, in a wind tunnel, the model under test may be suspended from one or more wires, and either prevented by a dynamometer from drifting down stream, or allowed to drift without rotation—catapultwise—till the obliquity of the suspension prevents further displacement. Both methods have been used in various laboratories for more than a decade.

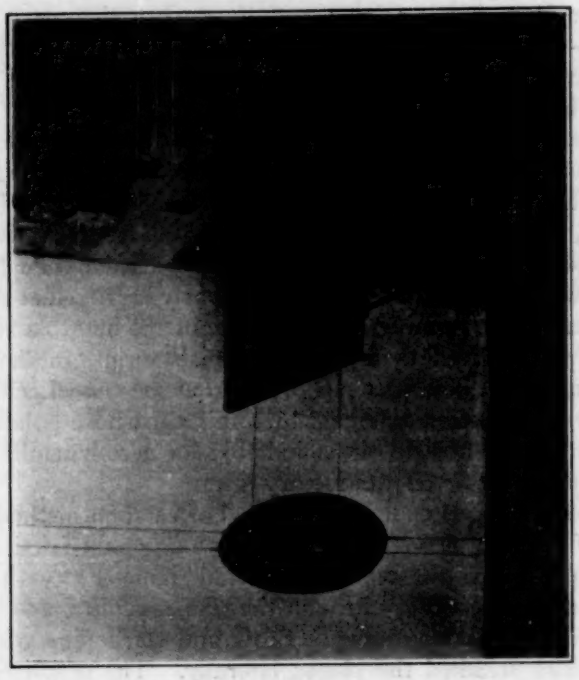
An example of the first method is found in the measurements of balloon resistance, first by Professor Prandtl of Göttingen University, and later by the National Physical Laboratory of England. Prandtl, in 1909, suspended Parseval hull models from the ceiling of his tunnel by four fine wires; two attached to the bow and sloping upward right and left; two similarly arranged at the stern. A mooring wire, running from the nose of the hull to a bell-crank balance arm, served to measure the resistance. In the British arrangement the bow was supported from the tunnel ceiling by a single wire, the stern was held by a tail pin whose pointed outer end rested in a hole in the spindle of an aerodynamic balance. Both apparatus proved satisfactory in use.

In 1902, the writer used the second or catapult method for the study of friction planes and aerofoils. Long skin-friction planes were supported at the centre of a wind tunnel by two fine steel wires running vertically through the tunnel ceiling, and attached to the top of the laboratory. Prow and stern pins gliding between stops steadied the planes laterally. The displacement of one suspension wire, carrying a sharp pointer along a fine steel scale lying on top of the tunnel, served to indicate the resistance of the friction board. Sometimes also four vertical wires, running from the corners of a large aerofoil up to a tiltable suspension frame, served to set the model at any incidence and to measure simultaneously its lift, drag and pitching moment. The tiltable frame feature was added in 1902 by Mr. H. Mattullath.

* Communicated by the Author.

Description of Bifilar Balance.—A bifilar balance, designed by the writer, is used at the Washington Navy Yard to measure the resistance of balloon hulls, struts, etc. Figs. 1 and 2 show the form of swing used for the study of hulls. Two steel wires, .02 inch in diameter, attached to the laboratory ceiling, run down through fine movable slots and a wind shield in the tunnel ceiling, and support the model near the middle of the air stream. At each

FIG. 1.



Airship hull suspended on bifilar windbalance.

end a ⅛ inch steel pin, gliding freely through an eyelet in a very fine stay wire stretched across the tunnel, steadies the model laterally.

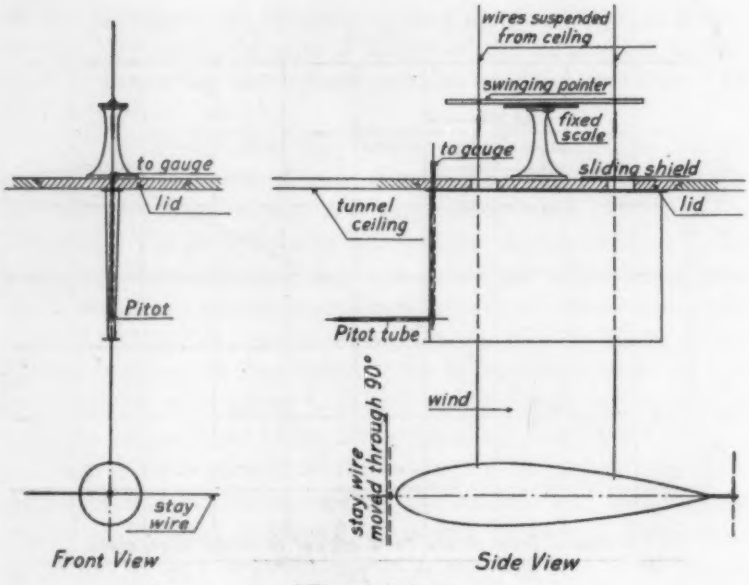
Above the tunnel a pointer fixed to a cross-bar joining the two suspension wires moves along a steel scale and when read with a lens indicates the deflection to a fraction of one-hundredth of an inch. The scale reading multiplied by the suspended weight,

divided by the length of wire above the scale, equals the deflecting force.

Very uniform and consistent readings are thus obtained. The air speed measured by the pitot-static tube fixed before the wind shield bears a known and fixed relation to the speed in the region where the model is to be inserted.

A well-shaped balloon hull can be placed about one diameter

FIG. 2.



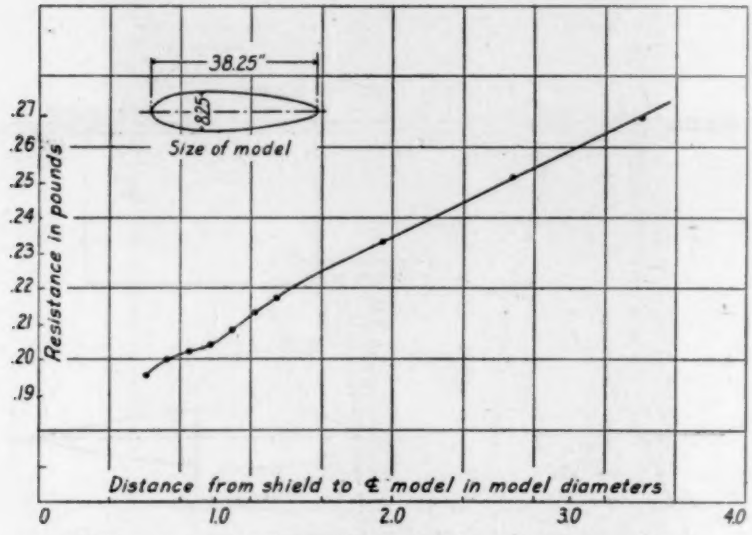
Bifilar windbalance.

from a suitable wind shield without blanketing or interference. This conclusion follows from observations of the air resistance of such a hull when held close to the shield, then successively further below it. The actual values of the resistance of a Parseval model in such a test are given in Fig. 3, together with the dimensions of the model and shield. Beyond two diameters, or somewhat nearer, the resistance of the model and its sustaining wires is directly proportional to its distance from the shield, that is proportional to the length of wire exposed. It is assumed that blanketing will be obviated by placing the model farther from the

wind shield than the distance represented by the curved part of the diagram in Fig. 3.

In another form of the bifilar balance the steel suspension wires support a heavy horizontal iron bar just within the bottom of the wind shield. From this bar light models may be suspended by fine wires running down into the wind. The bar is prevented from rolling by vertical lugs at its end, to which lugs the suspension wires are attached. It is steadied laterally by prow and stern pins running through holes in the wind shield. The front pin may

FIG. 3.



Resistance in terms of distance from wind shield. Wind speed 50 M. P. H.

serve as a holding stem for certain wind models, such as spheres, discs, cylinders, struts, etc. The horizontal bar can be loaded to any desired weight, to balance the air drag, by adding supplementary bars.

All forms of the balance require small corrections in the readings to allow for the resistance of the suspension wires and the disturbance of the air flow caused by them about the model. The method of making these corrections need not be detailed here.

Practical Usefulness.—In practical operation the swing balance has always proved satisfactory. It causes a minimum dis-

turbance of airflow about the model; it measures accurately; it is too simple to be erratic or uncertain in action. The resistance values obtained with it on models in a uniform wind, at ordinary flying speeds, usually plot on logarithmic paper as quite rectilinear, showing uniform consistency in the readings.

Origin.—In June, 1902, the writer described to the American Association for the Advancement of Science a swing balance, of two or more wires, as part of the equipment he had devised for the aerodynamic laboratory erected in 1901 in his department at the Catholic University of America; and in the *Philosophical Magazine* for July, 1904, he gave a sketch of the instrument as employed in measuring atmospheric friction on plane surfaces. The 1902 description follows:

"Another device that may prove valuable is known as the 'swing.' This consists of two or more fine steel wires fastened near the laboratory ceiling, and suspending wind objects inside the tunnel. The air resistance causes these objects to move down stream, and the consequent displacement of the wires, along their slots in the tunnel ceiling, is measured by a fixed meter-stick. The manner of using this instrument need not be given in detail, for its mechanical theory is very simple. An interesting feature of it is that, when the wind thrust is parallel to the tunnel, its magnitude is directly proportional to the deflection along the meter-stick.

"One valuable purpose of the 'swing' is to support long skin-friction boards or planes, within the tunnel, and indicate the amount of the skin resistance. Another important function is the support of very large aeroplanes at low angles of wind impact —planes which would not keep their shape if held in the usual way."

It may be added that the two front suspension wires ran up to prongs on one weighing axle, the two rear wires to prongs on another axle, both planted on a tilting frame which served to adjust and measure the incidence. The two weighings thus determined the lift and pitching moment. The drag could be computed from the down-stream displacement or measured by a nose wire attached to a weighing beam. This tilting-frame wire balance and the simple bifilar balance anticipated by many years the similar balances used in the aerodynamical laboratories of Europe.

Effect of Finely Divided Material on the Freezing Point of a Liquid.—F. W. Parker of the University of Wisconsin has studied this problem. (*Jour. Am. Chem. Soc.*, 1921, xliii, 1011–1018.) The finely divided, insoluble substances included ferric hydroxide, aluminum oxide, silica, and a silt loam; the liquids were water, benzene, and nitrobenzene. Determination was made of the freezing point of the mixture obtained by moistening a finely divided substance with one of the liquids. From a series of such determinations it was found that finely divided material produces a depression of the freezing point of a liquid, when that liquid is present as a film or in the capillary condition in the solid material. Moreover, the freezing point depression due to solid material and that due to material in solution are additive. Therefore the concentration of the soil solution cannot be determined by the freezing point method unless the moisture content be very high.

J. S. H.

The Glarimeter, an Instrument for Measuring the Gloss on Paper. L. R. INGERSOLL. (*Jour. Optical Soc. Am.*)—When light falls on a piece of paper, part of it is diffusely reflected and part is reflected specularly—that is, as from a mirror. This latter part is found by experiment to be almost completely plane polarized, when its angle of incidence on the paper is about 57.5 degrees. An eye-piece is set so as to receive the specularly reflected beam which has mingled with its also diffused light. Gloss is defined as the fraction of the brightness of the composite ray due to the plane polarized light contained in it. This constituent of the beam is eliminated by passing the light through a nicol and from the setting of the latter it is possible to calculate the desired fraction. There still remains an arbitrary element, the angle subtended by the source of light, and since this is so the author takes the angle through which the nicol must be turned from a certain setting as a convenient, though not an absolute, measure of the gloss. On this scale blotting paper reads 20 degrees; Solio, 50; ordinary magazine paper, 25 to 40. An absolute determination of the gloss as above defined can be got by using two different angles of incidence.

The instrument, the glarimeter, is portable and strong. Only 15 or 20 seconds are needed for a determination, and darkening the room is not necessary. Its use is not limited to paper. The gloss of paints, varnishes, textile fabrics and finishes can be investigated with it. Its special employment seems to be for controlling the calendering process of papers.

The instrument in its general outlines was devised some years ago, but the famine of optical parts during the war delayed its completion. Keisel, in Germany, appears to have developed a similar instrument independently, though later. G. F. S.

THE LUKENS ODOMETER.

HENRY R. TOWNE and COLEMAN SELLERS, JR.
Members of the Institute.

At the Stated Meeting of the Institute, held on the evening of Wednesday, April 20, 1921, Mr. Henry R. Towne, of New York City, member of the Institute, presented to the Institute for its collections an apparatus for measuring the distance traveled by vehicles, made by Mr. Isaiah Lukens, early in the last century. Mr. Coleman Sellers, Jr., Vice-president of the Institute, gave an account of the life and work of Mr. Lukens; and Mr. Henry R. Towne, in presenting the odometer, described its construction and operation.

Mr Sellers said:

There will be presented to the Institute this evening, by Mr. Henry R. Towne, of New York, an odometer, constructed in the early part of the last century, by Isaiah Lukens, an early member of the Institute.

It will add, perhaps, to the interest attaching to this piece of apparatus to consider for a few moments, the character and attainments of the maker. Unfortunately, there does not appear to be very much printed material relating to the life of Isaiah Lukens. In the December number of the Franklin Institute Journal, 1846, there was a brief biographical sketch, very appreciative of Mr. Lukens, but not accurate in respect to his genealogy.

Isaiah Lukens was descended from Jan Lucken, whose family was one of the thirteen families who followed Daniel Pastorius to Pennsylvania from Crefeld, in lower Germany, landing in Philadelphia October, 1683.

It will be recalled that when William Penn was arranging for the settlement of his colony, he entered into negotiations with a body of German Menonites, whose religious views corresponded in many respects with those of the Society of Friends, or "Quakers" as they were derisively called. These peace-loving Germans, mostly people of substance were seeking a land where they would be free from persecution. They purchased from William Penn a tract now forming that part of Philadelphia known as Germantown, comprising, it is said, 15,000 acres, which some authorities say was afterward increased to 25,000 acres. The price paid was 5 shillings for 100 acres, or 38 pounds sterling for the whole 15,000 acres.

Some of the descendants of Jan Lucken removed to Mont-

gomery County, where they were generally remarkable for their skill and ingenuity. One of them, John Lukens, was Surveyor General of the Province, and was noted for his ability as a surveyor and mathematician. Seneca Lukens, the father of Isaiah, was a farmer at Horsham, in Montgomery County, who also carried on the business of a clock and watchmaker, and it was from him that Isaiah, who was born in 1779, acquired his knowledge of the art. On coming of age, he joined his father in business.

His country environment, however, did not afford him full scope, and about 1811 he removed to Philadelphia, where he soon established a reputation for his mechanical and scientific ability and made a prominent place for himself in the community, especially among those who, like himself, were interested in the development of natural science.

Probably Mr. Lukens came most prominently before the general public in those early days through his exposure of the fraudulent character of the so-called Redhoeffer perpetual motion. In 1812, Charles Redhoeffer constructed a machine which appeared to run without the application of any power, the real motive power being so adroitly concealed that large numbers of people were deceived. The Legislature of Pennsylvania actually appointed a commission, "to make a strict examination of the machine invented by Chas. Redhoeffer, and to make a specific representation respecting its alleged importance as the public expectation required." Nathan Sellers and Oliver Evans, the inventor of the high-pressure steam engine, were among the members of this commission. The commissioners were unsuccessful in exposing the fraud, as they were not permitted to probe too deeply; but they were none the less convinced that the device was fraudulent. It was said that Mr. Lukens, who was present, remarked that the motion of the machine was very indicative of a crank turned by hand power. He then proceeded to make a model along the lines of the Redhoeffer machine; but operated by a concealed spring. This model is in the collection of The Franklin Institute and is one of its most valued possessions.

Having made some improvements in certain surgical instruments which had been invented by a surgeon in Paris, Lukens visited Europe for the purpose of introducing his inventions. He was unsuccessful in this effort but secured employment as a clock and watchmaker, and specialized in the making of chronometer

springs and surgical instruments, in which he was very successful owing to his methods of tempering steel. He remained in England and France for about three years, when he returned to Philadelphia.

In 1828, he was employed in making clocks for public buildings in Philadelphia and elsewhere. Among those constructed for Philadelphia buildings may be mentioned the clock in Independence Hall, the Bank of the United States, the Philadelphia Bank and others, all of which were excellent pieces of apparatus. On account of his ability as a mathematician he was assigned the duty of making the necessary observations for correcting the city time. These observations were made with his own transit instruments and were of great value for the regulation of marine chronometers.

He was active in the establishment of The Franklin Institute and was chosen as Vice-president at the first election held by the Society, which was on the 16th of February, 1824. From that time until his death on the 12th of November, 1846, he was an energetic and useful member. The writer of the memorial in the Journal speaks of him as follows: "He was eminently useful; freely yielding his time and attention to the various duties which he was required to perform—and by his advice and assistance aiding and supporting the Institute in its various operations for the benefit of science and the useful arts. His punctuality, diligence and intelligent service on committees appointed for the investigation of many important subjects will long be remembered among us, while the kindness of his disposition, and the many amiable and excellent qualities of heart and mind endeared him to an eminent degree to those who enjoyed opportunities of familiar intercourse with him."

Throughout his connection with the Institute, he was chairman of the Committee on Inventions, which later became the Committee on Science and the Arts.

Isaiah Lukens was not merely a highly skilled craftsman. As the record shows, he was really a scientific man of considerable ability and wide versatility. Besides dabbling in astronomy, he was interested in mineralogy and also, as his memorialist says: "Felt a lively interest in the progress of useful improvements, and from his general knowledge and habits of close investigation was well qualified to judge of their merits—encouraging such as were deserving, by his approval and influence."

As an example of Isaiah Lukens' wide interest in scientific matters, he constructed from a written description, two magneto-electric machines, and one of these is in the possession of The Franklin Institute. The original apparatus invented and constructed by Joseph Saxton was exhibited and described at a meeting of the British Association for the Advancement of Science in 1833. In 1834 it was brought to the atttention of the Institute by Prof. Alexander D. Bache, at which time one of the Lukens' machines was used to illustrate the subject.

He was a member of the American Philosophical Society and of the Academy of Natural Sciences.

Throughout the ninety-seven years of its life, The Franklin Institute of the State of Pennsylvania has been fortunate in having in its membership men of great ability who have devoted themselves unselfishly to the work of the Institute, and among these, not the least, was Isaiah Lukens.

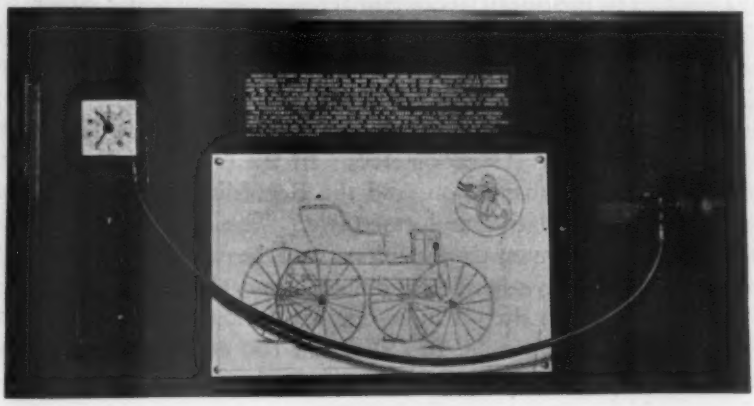
Mr. Towne, in presenting the apparatus, said:

The men who are regarded as dreamers and visionaries by their own generation are often recognized as prophets or discoverers by later generations. A " dreamer " in this sense was the Marquis of Worcester, whose " Century of Inventions," published about 250 years ago, described machines and processes, most of which were unknown and unattainable in his day, but many of which have since become realities. The most notable " discoverer " in this sense probably was Leonardo da Vinci, who lived some 400 years ago, who was one of the greatest of the Italian painters, and who is best known as such, but who was equally great as an engineer, administrator, and inventor. He not only conceived inventions but also made many drawings and practical models embodying them, and thus anticipated by several centuries some of the great achievements of our day.

Philadelphia has had its " dreamers " and inventors, and still better, its men of achievement. It is the birthplace of many of the important advances in the mechanic arts made during the past century, and the roll of its citizens who have made notable contributions in this field is a long one. Among these names, that of Isaiah Lukens may properly be included, as is evident from the very interesting sketch by Mr. Sellers of his life and achievements, to which we have just listened.

The "Odometer," which it is my pleasure to present to The Franklin Institute this evening, is an excellent example of Mr. Lukens' skill, both as a designer and a mechanic, having been made, as I believe, by his own hands. The instrument itself (in the left-hand upper corner of the case) has continuously been in the possession of my father or myself since Mr. Lukens' death. The driving gear on the wheel-hub, and the flexible shaft connecting it with the Odometer, are accurate reproductions of the originals, made, from my description, by Mr. Francis H. Richards, of New

FIG. 1.



The Lukens Odometer.

York, who generously has contributed these parts and the effective mounting of the exhibit. The inscription within the case reads as follows:

"Odometer" (Distance Measurer). A device now commonly, but less accurately, designated as a "Cyclometer" or "Speedometer." This instrument was made, probably between 1830 and 1840, by Isaiah Lukens, of Philadelphia, a leading instrument maker of his day, a man of considerable scientific attainment, and the Vice-president of The Franklin Institute at the time of its organization.

At the sale of Mr. Lukens' effects, after his death, this "Odometer" was bought by the late John H. Towne, of Philadelphia, by whom it was used for many years on a carriage. At his death it passed to his son, Henry R. Towne, now of New York, who also used it on carriages about 1880-90, by whom it is now presented (April, 1921) to The Franklin Institute.

The instrument itself is as originally made by Mr. Lukens, and is a

beautiful and ingenious piece of mechanism. The driving gear on the hub of the carriage wheel, and the flexible shaft connecting it with the "Odometer," are accurate reproductions of the original parts. These parts, together with the drawing and the mounting, have been contributed by Mr. Francis H. Richards, of New York.

It is believed that this instrument was the first of its kind, and anticipates all the modern devices for like purposes.

The use of a wheel by surveyors for measuring distances, especially for road maps, is very old. The names usually applied to it were "measuring wheel" or "perambulator." The wheel was provided with a single shaft, by which it was pushed or pulled over the road to be measured, its circumference usually being either 10 feet or some aliquot part of a mile. In some cases it had attached to the shaft a counter to indicate the number of revolutions or the distance covered. This crude device was developed by Mr. Lukens into a form which embodies all of the essential elements of the "cyclometers" and "speedometers" of the present day, namely, the Drive, the Transmission, and the Recording Instrument, the latter being cumulative and resettable. The mechanism of the Recording Instrument is ingenious and beautifully simple. It consists only of three spindles and five worms, all of the latter being "skewed." It has three hands, one revolution of each of which shows respectively 1 mile, 10 miles, and 100 miles, its cumulative reading thus covering 111 miles—an ample provision for horse-drawn vehicles.

Its adaptation to any vehicle was effected by providing the hub gear with the proper number of teeth. For example, if the front wheel of the vehicle were 3′ 6″ in diameter (its circumference thus being almost exactly 11′), the hub gear should have 11 teeth, as in this model, and would make one revolution for each seventeen revolutions of the wheel. The ratio of this gear to the wheel required to give absolute accuracy is 17.14, and the error resulting from the ratio of 17 to 1 is thus 43½ feet per mile, or .00825 per cent.

I take great pleasure in presenting to the Institute this interesting example of the clever work of one of Philadelphia's early scientists and mechanicians, and thus returning the Lukens Odometer to its birthplace.

NOTES FROM THE RESEARCH LABORATORY EASTMAN KODAK COMPANY.*

THE SETTING AND MELTING POINTS OF GELATINE.[1]

By S. E. Sheppard and S. S. Sweet.

[ABSTRACT.]

POSSIBLE definitions of "melting point" and "setting point" of jellies are discussed. It is suggested that theoretically these would be defined incidentally by the temperature at which the "time of relaxation" became infinite, the viscosity remaining finite. Practically it is agreed that they may be arbitrarily defined by standardized exceptional conditions. An apparatus for determining both "setting points" and "melting points" is described, in which use is made of an electrically controlled intermittent air-current at small constant pressure. Characteristic curves with concentration of gelatine as abscissae are given in comparison with jelly strength curves, and the results applied to grading commercial gelatines.

Stones Absorb Water. (*U. S. Geological Survey Press Bulletin No. 472*, June, 1921.)—Stone is by no means impervious to water. Some kinds, notably coarse sandstones, hold a large percentage. Even marbles absorb considerable quantities. The absorptive capacity of limestones ranges from 7 per cent. or more down to practically zero. Porous limestones, in which the pore space ranges from 10 to 15 per cent., will absorb from 4 to 6 per cent. of water, whereas semicrystalline and crystalline limestones or marbles have lower percentages of pore space and of absorption, such marbles as those from Vermont, Tennessee, and Georgia being almost non-absorbent. Pumice stone, which is usually lighter than water owing to its great amount of pore space, will absorb large quantities of water; obsidian and volcanic glass, which are of the same chemical composition as pumice stone, but several times heavier than water, will absorb none. Quartzite, granite, and the numerous eruptive rocks are practically impervious to water.

* Communicated by the Director.

[1] Communication No. 110 from the Research Laboratory of the Eastman Kodak Company, published in *J. Ind. Eng. Chem.*, 1921, 13, 423.

Henry A. Bumstead. LEIGH PAGE. (*Am. Jour. Science,* May, 1921.)—On the last day of 1920 American science suffered a notable loss by the death of H. A. Bumstead, who died on the train while on his return from a meeting of the American Physical Society. While a mere stripling he fell under the spell of the brilliant and erratic Rowland at Johns Hopkins, while later he became the friend of J. Willard Gibbs.

His papers dealt with the application of Maxwell's equations to electric waves, with electro dynamics. He investigated the radio-active character of Connecticut well water and of soil water and from this deduced the atomic weight of radium emanation. In the Cavendish Laboratory he studied the heating effects of X-rays on metals. Later the delta and the alpha rays claimed his attention. The Sloane Laboratory at Yale is a monument to his foresight. During the war he was Scientific Attaché to the British Embassy, and at the time of his death he was at the head of the National Research Council. Writer, investigator, lecturer and college teacher he wielded an influence that will long be felt in the scientific life of the United States. G. F. S.

The Structure of the Helium Atom. I. LANGMUIR. (*Phys. Rev.,* March, 1921.)—Bohr's models of the hydrogen atom and of the positively charged helium ion are now widely accepted. Since the fine structure of the lines of these two elements can be explained in detail from the models, there is good reason to hold that the models correspond to structural facts. Bohr's model of the helium atom, however, is not so successful in furnishing an explanation of the spectrum or of other properties. He assumes that the two electrons revolve about the central nucleus in one circular orbit. Langmuir first tries a model in which the two electrons rotate in the same direction in different circular orbits, whose planes are equally distant from the nucleus. Consideration shows that this type of structure must be discarded, since it turns out to be unstable. A second type is then suggested in which the two electrons move in the same circular orbit, but each traverses somewhat less than a semi-circle and keeps to its own half of the circle. The electrons move along the circle so that they would meet were the motion to continue. As they approach their mutual repulsion retards their motion. They stop and turn back and go through the same change of velocity near the other end of the semi-circle. They never get to the very end.

For this second type the ionizing potential comes out equal to 25.62 volts, which agrees well with the results of two experimental determinations by different observers, *viz.,* 25.7 and 25.5 volts. Other tests must be applied, but at least the new type of helium atom is worthy of serious consideration and may on closer inspection and longer acquaintance prove itself capable of explaining all that remains to be explained. G. F. S.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

ALEXANDRIA SENNA CULTIVATED IN INDIA.[1]

By C. J. Zufall.

[ABSTRACT.]

ALEXANDRIA SENNA from the Sudan has been found to be adulterated with the leaves of *Cassia obovate,* or dog senna, as well as with Arabian or Mecca senna. This form of adulteration is difficult to detect in grades known as "broken," "half leaf," or "siftings;" in fact, it is difficult to detect the presence of any foreign leaf in these grades if the adulterant is broken. Any form of adulteration is readily noticed, however, in the cultivated, hand-picked Alexandria senna from India because it consists almost entirely of whole leaves.

SOME OBSERVATIONS OF CORN MEAL IN STORAGE.[2]

By L. H. Baily and C. Thom.

[ABSTRACT.]

FOUR lots of corn meal ranging in water content from 12.5 per cent. to 16.6 per cent. were stored under well-ventilated conditions from April to August. One-half of each lot was unbolted meal. Subsamples of each lot were stored in glass in the laboratory.

In the well-ventilated samples the acidity, as determined by the method of Black and Alsberg at the close of the experiment, ranged from 53 to 65 degrees. No sourness, rancidity, lumpiness, moldiness or mustiness was detectable. Baking tests from each lot produced an acceptable product.

In the samples in glass, moldiness was evident in all samples having a moisture content of 14 per cent. or higher. None of these samples were in a merchantable condition.

*Communicated by the Chief of the Bureau.

[1] Published in *J. Am. Pharm. Asso.*, 1921, 10, 185.

[2] *Operative Miller*, 1920, 25, 368.

STUDIES IN NUTRITION. VI. THE NUTRITIVE VALUE OF THE PROTEINS OF THE LIMA BEAN, *PHASEOLUS LUNATUS.*[3]

By A. J. Finks and Carl O. Johns.

[ABSTRACT.]

A DIET of cooked lima bean meal supplemented with 0.3 per cent. of cystine, together with the other necessary non-protein dietary ingredients, furnish adequate protein for the normal growth of albino rats. A similar diet to which no cystine was added merely maintained the weight of the experimental animals. Growth did not occur if the diet consisted of either raw or cooked lima bean meal which was not supplemented with cystine, although the other non-protein dietary factors were added.

STUDIES IN NUTRITION. VII. THE NUTRITIVE VALUE OF THE PROTEINS OF THE ADSUKI BEAN, *PHASEOLUS ANGULARIS.*[4]

By Carl O. Johns and A. J. Finks.

[ABSTRACT.]

RAW or cooked adsuki bean meal supplemented with cystine furnished adequate protein and water-soluble vitamine for normal growth. Similar diets without the addition of cystine enabled the albino rats to grow at only one-third to two-thirds of the normal rate. Comparable results were obtained with the isolated adsuki bean globulin.

Dinitrosalicylic Acid—a Reagent for Glucose. JAMES B. SUMNER and V. A. GRAHAM, of Cornell University (*Jour. Biol. Chem.*, 1921, xlvii, 5–9), recommend 3,5-dinitrosalicylic acid as a reagent for glucose. The sodium salt of this acid reacts with glucose in the presence of sodium hydroxide at the temperature of boiling water to form a highly colored soluble nitroamino compound. The reaction may be used for the colorimetric determination of glucose. The color with dinitrosalicylic acid is not given by acetone or creatinine, but may be given by uric acid, polyhydric phenols, and other reducing sugars under certain conditions. J. S. H.

---

[3] Published in *Am. J. Physiol.*, 1921, **56**, 205.

[4] Published in *Am. J. Physiol.*, 1921, **56**, 208.

NOTES FROM THE U. S. BUREAU OF MINES.*

NATURE OF SHALE OIL OBTAINED FROM BUREAU OF MINES ASSAY RETORT.

By Martin J. Gavin and Lewis C. Karrick.

MANY inquiries have been received as to the quality of oil obtained from the assay retort developed and used by the Bureau of Mines, when it is operated under conditions most suitable for producing the highest yields of oils.

Experiments in the bureau's laboratories indicate that the quantity and quality of oil obtainable with the retort from a given shale can be varied by varying the conditions of retorting. For purposes of comparison, distillation analyses were made of a Scotch commercial shale oil; oil obtained from Scotch shale in the assay retort; oils obtained from an oil shale from Soldier's Summit, Utah, by the assay retort at two and five-hour rates of retorting; and a sample of Pennsylvania crude oil.

(a) The oil from Scotch shale by the assay retort is somewhat superior to that produced in commercial operations in Scotland, except as regards unsaturation percentage. The difference in unsaturation percentage, however, is small.

(b) The oil produced from the Soldier's Summit shale by the assay retort is nearly equivalent to that made from Scotch shale both by commercial operations in Scotland and by the assay retort in the laboratory, except as regards percentage of unsaturation. This is a quite important point, as unsaturation percentage is an indication of the relative magnitude of refining losses. The Soldier's Summit shale oil apparently contains a higher percentage of paraffin wax than the other oils examined, as indicated by setting points of the crude oils and the percentages and setting points of the vacuum fractions.

(c) The five-hour retorting period produced a lower yield of oil than the two-hour run, but the quality of the oil produced in the longer period was somewhat better. The slight difference in

* Communicated by the Director.

quality is largely offset by the greater yield of the shorter run, and also by the actual saving in time, fuel, etc., in making a retorting test.

(d) The Pennsylvania crude is superior to the shale oils except in paraffin content, as indicated by setting points.

It is interesting to know that the best oils thus far produced in the laboratory from both Scotch and American shales have been made in the assay retort. In no case, by any retort thus far used in the laboratory, have oils been made from American shales that are fully equal in quality to Scotch shale oils. Tables showing the results in detail have been published in a recent paper.

QUANTITATIVE MICROSCOPIC DETERMINATION OF COPPER SULPHIDES IN PORPHYRY ORE.

By R. E. Head

IN commercial plants and laboratories working on porphyry copper ores, it is frequently desired to ascertain the approximate proportions in which the copper sulphides and pyrite exist in the ore. Recently the writer had occasion to conduct such an analysis on an ore carrying chalcopyrite, chalcocite and bornite, besides pyrite. As chemical methods offered little possibility of yielding the desired information, a microscopic method was employed. The ore, in crushed condition, was prepared in small briquettes with sealing wax, the surface polished, the relative number and area of the grains of the different minerals in the polished surface determined under a microscope by use of a net-ruled micrometer disk, and the relative proportions of the different sulphides calculated by a modification of the Rosiwal method. This procedure gave the data desired. It offers interesting possibilities for use by metallurgists and chemists in affording approximate results for checking efficiency of flotation or other treatment plants, where chemical analyses are not available, and supplies useful information on the physical characteristics of the ores being treated. The method used is more fully described in a recent report issued by the bureau.

GASES FROM USE OF CARBON TETRACHLORIDE FIRE EXTINGUISHERS IN MINES.

By A. C. Fieldner and S. H. Katz.

Recent experiments with carbon tetrachloride fire extinguishers in the experimental mine corroborate the results of earlier laboratory tests, that the gases produced contain small quantities of irritating and poisonous gases which may be dangerous in closely confined places where the user cannot escape breathing the fumes. Hence care must be observed in the use of fire extinguishers of the carbon tetrachloride type in underground fire fighting. Details are given in a recent report of the experimental work which has been carried on at Pittsburgh.

Diathermy of Ice, Water and Steam. S. L. Brown. (*Phys. Rev.*, March, 1921.)—The radiation from an electric furnace was allowed to fall on a resistance element several feet away. When the stream of radiation changed the temperature of the element changed. This caused a change of resistance, which was easily measured. From a change in the resistance it was possible to calculate the change in the radiation received. First the unobstructed radiation from the furnace fell on the element, then a sheet of water was placed in its path. From the change of resistance was calculated the fraction of the radiation absorbed. When steam was tried care was taken that no condensation occurred. By varying the temperature of the furnace the radiation characteristic of different temperature intervals was investigated.

The per cent. of total radiation transmitted by a sheet of ice increases greatly as the temperature of the source rises. The same is true of water. It is quite striking that half a millimetre of water transmits only 26 per cent. of the radiation from a source at 1000° C. No absorption whatever was detected in the case of steam.

G. F. S.

Acoustics of Large Auditoriums. C. R. Fountain. (*Phys. Rev.*, March, 1921.)—Even after large plush curtains had been hung in the New City Auditorium, Macon, Georgia, the voice of a speaker on the platform was inaudible in the middle of the building. This is 200 ft. by 130 ft. by 60 ft. high, roughly boarded up with many cracks. The author expected to find reverberation, but was disappointed in this. The remedy was to erect an inner stage which directed the sound energy toward the audience with a minimum number of reflections. The dropping of a pin could then be heard anywhere in the building.

G. F. S.

The Chemical News in a New Form.—The following, from an announcement in a recent issue of the *Chemical News,* will interest all chemists. While many will regret the disappearance of the form and style that has been familiar for over half a century, yet the publishers are not to be criticized unfavorably for adapting the periodical to the changed conditions of the science of chemistry:

"After much discussion and enquiry it has been decided to make an alteration in the appearance, and also the title and contents of the *Chemical News*. . . .

"The great advances that have, within the last twenty-five years, been made in the domains both of chemistry and physics, and the fact that these advances have been largely absorbed in our national industries, has brought the *Chemical News* into the hands of manufacturers and merchants to a very much greater extent than in the past.

"We are, therefore, venturing to alter the latter part of the title to *Journal of Industrial Science* and to make an appropriate alteration to the title-page of the volume. . . .

"Firmly believing that we shall before long enter upon a period when the present state of unrest and agitation will give place to one of serious work and production, it is our intention to lose no time in contributing our mite to the increasing activity in industrial science. We shall greatly value any suggestions and criticisms upon the course we are taking." H. L.

Asbestos. (*U. S. Geological Survey Press Bulletin No. 474,* July, 1921.)—The art of weaving the mineral fibre in asbestos, which is ordinarily indestructible, was rediscovered at a comparatively late period of civilization. Woven asbestos was used in the ancient pyre to preserve the royal ashes. Charlemagne is said to have had a tablecloth made of asbestos and to have cleaned it by throwing it into the fire, which consumed the dirt, thus illustrating in a spectacular manner one of the most valuable properties of this material.

The fibre of the best grade of asbestos is beautiful and silky and has great flexibility, elasticity, and tensile strength. It can be spun into thread so fine as to run 225 yards to the ounce, and as it is incombustible as well as a non-conductor of heat and electricity and resists the action of most ordinary acids, its field of use is large. The possible applications of asbestos are far from fully appreciated not only by the general public, but by manufacturers who are in search of material for special uses to which asbestos may well be applied. Perhaps it is most generally used to make fireproof cloth for theatre curtains. It has been used also for making firemen's clothing. Everywhere in cold countries it is extensively employed for covering furnaces, boilers, and pipes to prevent loss of heat. Asbestos is a good insulator.

THE FRANKLIN INSTITUTE.

LIBRARY NOTES.

PURCHASES.

CATHCART, E. P.—Physiology of Protein Metabolism, 1921.
COMEY, A. M., and D. A. HAHN.—Dictionary of Chemical Solubilities, 1921.
DESMOND, C.—Wooden Ship Building, 1919.
FREDERICK, R. C., and A. FORSTER.—Public Health Chemical Analysis, 1920.
JENKIN, C. F.—Report on Materials of Construction Used in Aircraft and Aircraft Engines, 1920.
KAHN, A. R.—Sugar, 1921.
KAYE, G. W. C., and T. H. LABY.—Tables of Physical and Chemical Constants, 1921.
MURKE, F.—Condensed Description of the Manufacture of Beet Sugar, 1921.
SPALDING, T. P.—Masonry Structures, 1920.

GIFTS.

Adams, J. D., and Company, General Catalogue No. 21, Road Building and Maintenance Machinery. Indianapolis, Indiana, no date. (From the Company.)
Agricultural and General Engineers, Limited, Road Making and Transport Plant for Local Authorities. London, England, no date. (From the Company.)
Alan Wood Iron and Steel Company, History of the Alan Wood Iron and Steel Company. Philadelphia, Pennsylvania, 1920. (From the Company.)
Allen General Supplies, Limited, Fuel-saving and Mechanical Equipment. Toronto, Canada, no date. (From the Company.)
American-LaFrance Fire Engine Company, Incorporated, Fire Fighting Equipment, Accessories and Supplies, Edition No.6 Elmira, New York, no date. (From the Company.)
Amsler, Alfred J., and Company, Metal Testing Machines and Equipments. Schaffhouse, Switzerland, no date. (From the Company.)
Anderson Die Machine Company, Bulletin No. 10. Bridgeport, Connecticut, no date. (From the Company.)
Armour Institute of Technology, Catalogue 1920–21. Chicago, Illinois, 1921. (From the Institute.)
Associated Tile Manufacturers, Publication No. K-200. Beaver Falls, Pennsylvania, 1921. (From the Manufacturers.)
Atlas Car Manufacturing Company, Catalogue No. 1180; Bulletins Nos. 1100, 1085, 1095, 1170, 1175, 1185, 1090, 1145, 1022. Cleveland, Ohio, no date. (From the Company.)
Atlas Valve Company, Bulletin No. 1-A, Edition No. 1. Newark, New Jersey, no date. (From the Company.)
Baker Manufacturing Company, General Catalogue No. 81, Road Tools. Springfield, Illinois, no date. (From the Company.)

Barber Asphalt Paving Company, Bulletin No. 2-B, Asphalt Mixing Plants. Philadelphia, Pennsylvania, no date. (From the Company.)

Bath, John, and Company, Incorporated, Bulletins Nos. 10 and 15. Worcester, Massachusetts, no date. (From the Company.)

Benjamin Electric Manufacturing Company, Catalogue No. 17, Industrial Lighting. Chicago, Illinois, 1919. (From the Company.)

Bogert and Carlough Company, Catalogue D-20. Paterson, New Jersey, no date. (From the Company.)

Boonton Rubber Manufacturing Company, "Boonton Bakelite." Boonton, New Jersey, no date. (From the Company.)

Boving and Company, Limited, "Boving Turbo Pumps." London, England, no date. (From the Company.)

Bowen Products Corporation, "Chassis Lubrication," "Lubricants and Their Application," "Random Thoughts on Tractor Lubrication." Auburn, New York, no date. (From the Corporation.)

Brampton Brothers, Limited, Catalogue, Power Transmission by Chain. Birmingham, England, no date. (From Brampton Brothers.)

British Steel Piling Company, The B.S.P. Pocketbook. London, England, no date. (From the Company.)

Buff and Buff Manufacturing Company, Catalogue of Surveying Instruments. Boston, Massachusetts, 1918. (From the Company.)

California Department of Engineering, Seventh Biennial Report, 1919-1920. Sacramento, California, 1921. (From the Department.)

Cambridge and Paul Instrument Company, Limited, List No. 194, Thermo-Electric Pyrometers. London, England, no date. (From the Company.)

Canadian Commission of Conservation, Water Powers of Manitoba, Saskatchewan, and Alberta. Toronto, Canada, 1916. (From the Commission.)

Canada, Department of the Interior, Annual Report of the Reclamation Service for 1919-1920. Ottawa, Canada, 1920. (From the Department.)

Canada, Department of the Interior, Dominion Water Power Branch, Annual Reports, 1917-18 and 1918-19; Water Resources Paper No. 25, Hydrometric Survey of British Columbia for the Climatic Year 1918-19. Ottawa, Canada, 1920–21. (From the Department.)

Carrington, H. V., Catalogue, Precision Machines. Westminster, England, no date. (From Mr. H. V. Carrington.)

Carter, James, Limited, Catalogues of Haulage Machinery, Rubber Machinery, and Chemical Plant. Stalybridge, England, no date. (From Mr. J. Carter.)

Catholic University of America, Year Book for 1921-1922, Washington, District of Columbia, 1921. (From the University.)

Chicago Baling Press Manufacturing Company, Modern Leader Baling Presses. Chicago, Illinois, no date. (From the Company.)

Chicago, Burlington and Quincy Railroad Company, Sixty-seventh Annual Report of the Board of Directors for 1920. Chicago, Illinois, 1921. (From the Company.)

Churchhill, Charles, Company, Limited, Catalogue of High-speed Steel Cutters. London, England, no date. (From the Company.)

City and Guilds, of London Institute, Annual Report for 1921. London, England, 1921. (From the Institute.)

Clark University, Catalogue 1920-1921. Worcester, Massachusetts, 1921. (From the University.)

Clothel Refrigerating Company, The Clothel System of Mechanical Refrigeration. New York City, New York, no date. (From the Company.)

Collis Company, Catalogue, "Wonder" Quick Change Chuck. Clinton, Iowa, 1921. (From the Company.)

Colorado State Engineer, Twentieth Biennial Report. Denver, Colorado, 1921. (From the State Engineer.)

Concord Board of Water Commissioners, Forty-ninth Annual Report, for 1920. Concord, New Hampshire, 1921. (From the Commissioners.)

Continental Car Company of America, Catalogue of Dump Cars. Louisville, Kentucky, no date. (From the Company.)

Coppus Engineering and Equipment Company, The Turbo Blower for Undergrate Draft. Philadelphia, Pennsylvania, 1920. (From the Company.)

Cutler-Hammer Manufacturing Company, Publication No. 875, The Thomas Meter, and Publication No. 876, Thomas Calorimeter. Philadelphia, Pennsylvania, no date. (From the Company.)

Dake Engine Company, Catalogue No. 28. Grand Haven, Michigan, no date. (From the Company.)

Denver Rock Drill Manufacturing Company, Booklet, Waughoist, Model No. 250. Denver, Colorado, no date. (From the Company.)

Delaware River Bridge Board of Engineers, Report to the Delaware River Bridge Joint Commission of the States of Pennsylvania and New Jersey on the Bridge over the Delaware River, Connecting Philadelphia, Pennsylvania, and Camden, New Jersey. Philadelphia, Pennsylvania, no date. (From the Commission.)

Detroit Twist Drill Company, Catalogue No. 19, Detroit Twist Drills. New York City, New York, no date. (From the Company.)

Detrick M. H. Company, Catalogue of Detrick Arches. Philadelphia, Pennsylvania, 1921. (From Mr. J. G. Thomas.)

Direct Separator Company, Incorporated, Catalogue S-21. Syracuse, New York, no date. (From the Company.)

Dravo-Doyle Company, Catalogue, Ten Years Progress in Water Works Pumps. Philadelphia, Pennsylvania, 1921. (From the Company.)

Dunham, C. A., Company, The Dunham Hand Book No.114. Chicago, Illinois, 1920. (From the Company.)

Dust Recovering and Conveying Company, Bulletins Nos. 9,11 and 12. Cleveland, Ohio, 1921. (From the Company.)

Electric Specialty Company, Bulletin No. 231, "Esco" High-voltage Generators. Stamford, Connecticut, 1921. (From the Company.)

Electric Power Equipment Corporation, Bulletin No. 202. Philadelphia, Pennsylvania, no date. (From the Corporation.)

Elliott Company, Bulletin C, High-grade Power Accessories. Pittsburgh, Pennsylvania, 1920. (From the Company.)

Engberg's Electric and Mechanical Works, Catalogue No. 301, Vertical Engines. St. Joseph, Michigan, no date. (From the Works.)

Erith's Engineering Company, Limited, Three-stage Combustion Stoker. London, England, no date. (From the Company.)

Farrell-Cheek Steel Foundry Company, The Illustrated Story of a Farrell-Cheek Steel Casting. Sandusky, Ohio, no date. (From the Company.)

Ferguson, H. K., Company, Catalogue of Better Buildings. Cleveland, Ohio, 1920. (From the Company.)

General Chemical Company, Catalogue, Making Poor Concrete Floors Good and Good Ones Better. New York City, New York, no date. (From the Company.)

Gifford-Wood Company, Mechanical Handling in all Lines of Industry. Hudson, New York, no date. (From the Company.)

Glenzer, T. C., Company, Catalogue No. 4, Utility Tools. Detroit, Michigan, 1921. (From the Company.)

Graver Corporation, Bulletins Nos. 506 and 507. East Chicago, Indiana, 1921. (From the Corporation.)

Griscom-Russell Company, Bulletins Nos. 330 and 350. Philadelphia, Pennsylvania, no date. (From the Company.)

Hagan, George J., Company, Bulletin LF 103, Liquid Fuel Burners. Pittsburgh, Pennsylvania, no date. (From the Company.)

Hampton, C. and J., Limited, Vice Catalogue, 1921 Edition. Sheffield, England, 1921. (From Messrs. C. and J. Hampton.)

Hanna Engineering Works, Catalogue No. 4, Riveters. Chicago, Illinois, no date. (From the Works.)

Harrison Safety Boiler Works, Sorge-Cochrane Hot Process Water Softener, Book of Instructions. Philadelphia, Pennsylvania, no date. (From the Works.)

Haynes Stellite Company, Bulletins Nos. 9 and 10. New York City, New York, 1921. (From the Company.)

Hayward-Tyler and Company, Limited, Practical Guide for the Water Supply. London, England, 1921. (From the Company.)

Hyatt Roller Bearing Company, Bulletin 1557. New York City, New York, 1919. (From the Company.)

Keller Pneumatic Tool Company, Circular No. 41. Grand Haven, Michigan, no date. (From the Company.)

Kelly, Robert, and Sons, Limited, Sectional Catalogues Nos. 1, 2, and 3. Manchester, England, no date. (From the Company.)

Kennedy Valve Manufacturing Company, Kennedy Valves. Elmira, New York, 1920. (From the Company.)

Kenney Brothers and Wolkins, Catalogue, Drawing and Manual Art Supplies. Boston, Massachusetts, no date. (From the Company.)

Keuffel and Esser Company, Catalogue of Drawing Instruments. New York City, New York, no date. (From the Company.)

Lackawanna Steel Company, Bulletin No. 109, Lackawanna Steel Sheet Piling. Lackawanna, New York, 1921. (From the Company.)

Lakewood Engineering Company, Better Good Roads for Maricopa County, Arizona; Specifications Sheets; Bulletins Nos. 20-B, 21-C, 23-B, 26, 29-D, 36. Philadelphia, Pennsylvania, no date. (From the Company.)

Leeds and Northrup Company, The Hump Method for Heat Treatment of Steel. Philadelphia, Pennsylvania, no date. (From the Company.)

Link-Belt Company, Book No. 475. Philadelphia, Pennsylvania, 1921. (From the Company.)

Ludlow Valve Manufacturing Company, Booklet, Ludlow Electrically Operated Valves. Troy, New York, 1921. (From the Company.)

Maine Water Power Commission, First Annual Report. Augusta, Maine, 1920. (From the Commission.)

Massachusetts Institute of Technology, Bulletins, Vol. 55, No. 18, Vol. 56, No. 6. Cambridge, Massachusetts, 1920-1921. (From the Institute.)

Michigan Department of Labor, Thirty-seventh Annual Report. Lansing, Michigan, 1920. (From the Department.)

Mine and Smelter Supply Company, Bulletin No. 64, Wilfley Concentrating Tables. New York City, New York, no date. (From the Company.)

Missouri School of Mines and Metallurgy, Catalogue, 1920-21. Rolla, Missouri, 1921. (From the School.)

New Departure Manufacturing Company, Catalogue, Ball Bearing Application. Bristol, Connecticut, 1921. (From the Company.)

New York Board of Water Supply, Fifteenth Annual Report for 1920. New York City, New York, 1921. (From the Board.)

Niebling, F. W., and Company, Catalogue No. 3, Ice and Refrigerating Machinery, Air Compressors. Cincinnati, Ohio, no date. (From the Company.)

Northern Engineering Works, Bulletin No. 508. Detroit, Michigan, no date. (From the Works.)

Norton Company, Booklet, Grinding in the Railroad Shops. Worcester, Massachusetts, no date. (From the Company.)

Ohio Agricultural Experiment Station, Monthly Bulletin, for May and June. Wooster, Ohio, 1921. (From the Station.)

Orton and Steinbrenner Company, Catalogue No. 19, Locomotive Cranes; Catalogue No. 17. Chicago, Illinois, 1921. (From the Company.)

Pittsburgh Transformer Company, Bulletin No. 2005, Pittsburgh Transformers. Pittsburgh, Pennsylvania, 1920. (From the Company.)

Porter-Cable Machine Company, "The Porter-Cable Lathe," Syracuse, New York, 1921. (From the Company.)

Ramapo Iron Works, Catalogue No. 20. Hillburn, New York, no date. (From the Works.)

Rickert-Shafer Company, Bulletin No. 7, Collapsible Taps. Erie, Pennsylvania, no date. (From the Company.)

Ridgway Dynamo and Engine Company, Bulletins 20, 22, 24, 25, 28 and 29. Ridgway, Pennsylvania, no date. (From the Company.)

Rockwell, W. S., Company, Bulletin No. 223, Oil and Gas Burners. New York City, New York, 1921. (From the Company.)

Root Company, "Census Takers of Industry." Bristol, Connecticut, 1921. (From the Company.)

Rand and Davis, Engineers, Incorporated, Bulletin No. 72, Rand System for Bunker Oil. New York City, New York, no date. (From Rand and Davis.)

Ryerson, J. T., and Son, Shop Handbook on Alloy Steels. Chicago, Illinois, no date. (From the Company.)

Sauerman Brothers, Pamphlets Nos. 11, 12, 14 and 15; Catalogue No. 7. Chicago, Illinois, no date. (From Sauerman Brothers.)

Scully Steel and Iron Company, Machinery Catalogue "S." Chicago, Illinois, 1917. (From the Company.)

Shatz Manufacturing Company, Catalogue No. 6, Commerical Annular Ball Bearings. Poughkeepsie, New York, no date. (From the Company.)

Shontz, H. B., Company, Incorporated, Battery and Electrical Service Station Equipment. New York City, New York, no date. (From the Company.)

Simonds Manufacturing Company, Catalogue No. 121, Simonds Steel. New York City, New York, no date. (From the Company.)

Skelton, R. A., and Company, Handbook No. 17. London, England, 1921. (From the Company.)

Smith and Coventry, Limited, Sensitive Drill Press, Section "F," Ninth Edition. Manchester, England, no date. (From the Manufacturers.)

Smith Locomotive Adjustable Hub Plate Company, Catalogue No. 6. Chicago, Illinois, no date. (From the Company.)

Société des Ingénieurs Civils de France, Annuaire, 1921. Paris, France, 1921. (From the Society.)

Société Franco-Belge, Album of Pictures of Locomotives with Tables of Weights and Dimensions. Paris, France, no date. (From the Society.)

Standard Alloys Company, Uranium in Steel. Pittsburgh, Pennsylvania, no date. (From the Company.)

Standard Machinery Company, 1920 Catalogue, Sixteenth Edition. Auburn, Rhode Island, 1920. (From the Company.)

Standard Scientific Company, Laboratory Apparatus. New York City, New York, 1921. (From the Company.)

State College of Washington, Annual Catalogue, 1921. Pullman, Washington, 1921. (From the College.)

Stephens-Adamson Manufacturing Company, Catalogue No. 26. Aurora, Illinois, 1921. (From the Company.)

Stokoe, C. L., Catalogue of "Monitor" Patent Safety Devices. Wallsend England, no date. (From Mr. C. L. Stokoe.)

St. Paul Board of Water Commissioners, Thirty-ninth Annual Report, 1920. St. Paul, Minnesota, 1921. (From the Commissioners.)

Strong, Carlisle and Hammond Company, Catalogue No. 24, Strong Stem Specialties. Cleveland, Ohio, no date. (From the Company.)

Stroud and Company, Catalogue No. 21, Road Making Machinery. Omaha, Nebraska, no date. (From the Company.)

Sullivan Machinery Company, Bulletin No. 72-E. Chicago, Illinois, 1921. (From the Company.)

Superheater Company, Complete set of Bulletins on Steam Superheaters. New York City, New York, no date. (From the Company.)

Syracuse University, Catalogue, 1920-1921. Syracuse, New York, 1921. (From the University.)

Terry, Herbert, and Sons, Limited, Catalogue, describing Springs. Redditch, England, 1921. (From the Company.)

Texas Company, Lubrication Guide for the Railroads. New York City, New York, 1921. (From the Company.)

Truscon Laboratories, Technical Pamphlet No. 8, Science and Practice of Integral Waterproofing. Detroit, Michigan, 1920. (From the Laboratories.)

Tucker, W. W. and C. F., Catalogues Nos. 2 and 6. Hartford, Connecticut, 1920. (From Messrs. W. W. and C. F. Tucker.)

Universal Boring Machine Company, Instruction Book and Bulletin on Boring, Milling, Drilling and Facing. Hudson, Massachusetts, 1920. (From the Company.)

Universal Drafting Machine Company, Catalogue, Universal Drafting Machines. Cleveland, Ohio, no date. (From the Company.)

United Fruit Company, The Story of the Banana. Boston, Massachusetts, 1921. (From the Company.)

United States Statistical Abstract for 1920. Washington, District of Columbia, 1921. (From the Department of Commerce.)

University of Arizona, Annual Catalogue for 1920-1921. Tuscon, Arizona, 1921. (From the University.)

University of California, Publications in Mathematics. Berkely, California, 1921. (From the University.)

University of Florida, Catalogue 1920-1921. Gainsville, Florida, 1921. (From the University.)

University of Idaho, Annual Catalogue for 1920-1921. Moscow, Idaho, 1921. (From the University.)

University of North Dakota, Catalogue 1920-1921. Grand Forks, North Dakota, 1921. (From the University.)

University of Vermont, Catalogue for 1920-1921. Burlington, Vermont, 1921. (From the University.)

U. S. Coast and Geodetic Survey, Results of Observations made at the U. S. Coast and Geodetic Survey Magnetic Observatory, 1917 and 1918; Publication No. 68, Elements of Map Projection. Washington, District of Columbia, 1921. (From the Survey.)

Vacuum Oil Company, Booklet, Correct Lubrication. New York City, New York, no date. (From the Company.)

Vanadium Corporation of America, Catalogue, Vanadium, the Master Alloy. New York City, New York, no date. (From the Corporation.)

Walker-Weston Company, Limited, Catalogue V, Patent Pyramidal Interlocked Reinforcement. London, England, no date. (From the Company.)

Ware Brothers Company, Vehicle Year Book for 1919. Philadelphia, Pennsylvania, no date. (From Mr. Charles E. Duryea.)

Watson Manufacturing Company, Watson Grangent Cut Box Tool. Toledo, Ohio, no date. (From the Company.)

Wayne Iron Works, Incorporated, Catalogue, Property Protection and Ornamentation. Philadelphia, Pennsylvania, no date. (From the Works.)

Wayne Machinery Company, A Trip Through the Plant of the Wayne Machinery Company. Fort Wayne, Indiana, no date. (From the Company.)

Webster and Perks Tool Company, Bulletins Nos. F-3, P-1, U-2, and B. Springfield, Ohio, no date. (From the Company.)

Wellman Bibby Company, Limited, The Coupling of Shafting. London, England, no date. (From the Company.)

Wellman-Seaver-Morgan Company, Bulletin No. 52, The W.S.M. Balanced Plunger Hydraulic Valve. Cleveland, Ohio, 1920. (From the Company.)

Wellman-Smith-Owens Engineering Corporation, Limited, Electric Wharf and Dockside Cranes. London, England, 1921. (From the Corporation.)

Western Wood Pipe Publicity Bureau, Catalogue of Wood Pipe. Seattle, Washington, no date. (From the Bureau.)

Wheel Trueing Tool Company, Diamonds and Diamond Pointed Tools. Detroit, Michigan, 1921. (From the Company.)

Whiting Corporation, Catalogue No. 145, Railroad Equipment; Catalogue No. 154, Foundries; General Catalogue. Harvey, Illinois, no date. (From the Corporation.)

Williams, G. H., Company, Williams Clam Shell Buckets. Erie, Pennsylvania, no date. (From the Company.)

Wood, R. D., and Company, Booklet, The Automatic Gas Producer. Philadelphia, Pennsylvania, no date. (From the Company.)

Yale and Towne Manufacturing Company, Catalogue 20-D, Hoists. Stamford, Connecticut, no date. (From the Company.)

Yale University, General Catalogue, for 1920-1921. New Haven, Connecticut, 1921. (From the University.)

BOOK NOTICES.

SOME MICROSCOPICAL TESTS FOR ALKALOIDS. By Charles H. Stephenson, Scientific Assistant, U. S. Bureau of Chemistry. Also including Chemical Tests of the Alkaloids Used, by C. E. Parker, Assistant Chemist, U. S. Bureau of Chemistry. 110 pages, 27 plates and a folding table of reactions, 8vo. Philadelphia, J. B. Lippincott Company.

This book comprises a very large amount of information; the collection involves much routine and laborious work. The plates each contain six photomicrographs reproduced by photogravure. We are told in the preface that the book is essentially the outcome of researches undertaken in 1907 for the purpose of obtaining microchemical tests for cocain, and the investigations were carried on until sixty-four different alkaloids were examined. It seems, however, that thirteen of these were of doubtful purity and have not been included in the work. Commendation must be given to the authors for their careful work, and for the general excellence of the plates. It may be, however, a question as to how far such results are of value to the professional toxicologist or pharmaceutic analyst. These tests were made with essentially pure samples, but in actual practice, especially in toxicologic work, unknown impurities are apt to be present and confusion arise from such conditions. It may be better in general for the analyst to prepare his own specimens from known substances and compare them with the crystals obtained from the material under examination. Of course, there is a danger here, inasmuch as the chemist who should be examining the contents of a stomach for strychnine would not like to have a solution of any strychnine salt near his working table, but that difficulty can be met by carrying out the comparison in some other place. Strychnine and brucine are mentioned as two of four alkaloids that give the greatest range of crystalline precipitates, and they are among those that give the most characteristic color tests.

It is interesting to compare the plates of this book with those of Doctor Wormley's Microchemistry of Poisons. The plates in that work are all steel engravings made by Mrs. Wormley, and many of them are marvels of drawing. Photomicrographic processes have rendered such laborious work unnecessary. It is to be noted that probably interesting results could have been obtained by the use of polarized light and also by plain light with color screens. No information is given as to the methods of making the photographs. The plates and text are well printed, but the paper used for the text is unnecessarily heavy and the type unnecessarily large. It is, indeed, a question why this work should not have appeared as a government bulletin.

HENRY LEFFMANN.

AMMONIA AND THE NITRIDES, WITH SPECIAL REFERENCE TO THEIR SYNTHESIS. By Edward B. Maxted, Ph.D., B.Sc., F.C.S. 18mo., viii, 112 pages, contents, index and 16 illustrations. Philadelphia, P. Blakiston's Son & Co. $2.00 net.

Nitrogen used to be considered as the type of the indifferent element, for even gold and platinum, notwithstanding their high resistance to the action of the air, were known to form a large series of compounds of great stability, while except as to the organic substances, the nitrogen compounds were chiefly noted for their instability. The discovery of the elements of the zero group displaced nitrogen from its position, and, in truth, the book before us shows that nitrogen has much chemical activity if it is given a chance. H. E. Armstrong, years ago, suggested that nitrogen might exist in an allotropic form, basing his views upon the large number of comparatively stable organic compounds, and recently, Strutt (now Lord Rayleigh) has obtained evidence of marked increase of the activity of free nitrogen under the influence of electric discharges. An account of these experiments is given by Dr. Maxted.

The chemist who has not paid attention to the field of the science will certainly be astonished at the large number of nitrogen combinations in the inorganic field. Of the numerous elements that are commonly regarded as essentially inorganic in their relations, fluorine seems to be the only one that is not mentioned as forming a nitride. As might be expected, nearly half of the book is devoted to the ammonia synthesis, a reaction that has been the subject of most extensive investigation, and which seems to have had a profound influence on the world's history, for it has recently been asserted on good authority, that if the Germans had not perfected the Haber process for producing ammonia, they would have been compelled to give up the fight in about a year, as the British blockade would have cut off the supply of nitrates, and left them without means for producing the modern high explosives.

The book is crowded with information along lines not presented in the ordinary text-books, or even in technologic works, and is a striking instance of the high specialization in modern science.

HENRY LEFFMANN.

MEMOIRE SUR LA CHALEUR, par MM. Lavoisier et De Laplace. 18mo., paper bound, 78 pages, two full-page plates. Paris, Gauthier-Villars et Cie, 1920.

This is another number of the series of reprints of the works of distinguished scientists of former years, the general title being "The Masters of Scientific Thought." Such essays are scarcely subjects of criticism, for the world's judgment on these scientists has long since been established, and they are now fully honored for their services. The essays make interesting and profitable reading, even though they bring no new information to the student, indeed, they sometimes contain statements now recognized as erroneous. The present work is a reprint of a paper published by the *Academie des sciences* in 1780. It is interesting to note the preliminary discussion on the nature of heat. The two theories, respectively, that heat is a substance diffused through all space penetrating all matter, and that it is due to motions of particles of matter, are presented, but the authors do not attempt to decide. The fact that the first theory has gone out of vogue suggests that future physics may dismiss equally to oblivion the theory of the ether, which is now so prominent in our text-books.

The book is very easy reading, but is printed on poor paper. The calorimeters used in the investigation are shown in detail in two fairly good plates. HENRY LEFFMANN.

LA PHYSIQUE DES RAYONS x per MM. R. Ledoux-Lebard et A. Dauvillier. 8vo., vii, 435 pages, index, 10 full page plates, numerous illustrations. Paris, Gauthier-Villars et Cie.

In this elaborate treatise on the subject of the X-ray we have a vast amount of detail, both practical and technical, and an introduction by de Broglie whose remarks may be conveniently taken as a general description of the nature and purpose of the book. The rôle played by X-rays in physics and in medical sciences continues to widen. It will also enter very soon into industrial applications. Unexpected discoveries have completely made over, in the last six years, our knowledge of this branch of physics, and, until the present time, no French work has presented in a complete form the most recent state of that knowledge. This work of MM. R. Ledoux-Lebard and A. Dauvillier has come to fill the gap. It will permit those who read it to follow the already considerable data that have been accomplished in recent progress, but it is not merely a chapter, a little scanty of the science which is about to take a new life, or merely a corner, a little dark, which has been cleared up and illuminated, for the book is a good deal more than that. The questions of which this work treats are in course of passing to the first rank of particular interest of modern physics. Why is it that the properties of the X-rays and of spectral analysis have acquired so important a bearing? It is essentially because it is a question of phenomena of high frequency, and that these very rapid periodical movements seem to be regulated by hitherto unknown and quite remarkable laws. The most salient fact, that which strikes us at the beginning, is the primary part played by the normal suc-

cession of the elements, that is to say the classification of simple bodies in the order of their increasing atomic weights. We cannot study the X-rays without studying chemistry at the same time, and without having to take up, indeed, a special chemistry, that of the simple substances. Everything in this domain is remarkably continuous and oriented. As soon as one sets the elements, according to their natural sequence, assigning to each a serial number, an integral number of necessity, this serves to fix completely a part played by the element considered with reference to the X-rays. No other department of physics offers anything comparable. We find nowhere an association as general and as harmonious. This natural order of the elements should, therefore, appear as fundamental to whoever wishes to study profoundly the rays of high frequency. But there is another point equally worthy of consideration, the law of Planck–Einstein or the relation of *quanta*, which binds the frequencies v to the energies W put in play by the relation

$$W = h\nu$$

in which h is a universal constant.

Perhaps all this will seem at first view a little ambitious and too far from practical application. This is not so. Certain experimental data new postulates, precise and directly utilizable, abound in the chapters of this book. All physicists, whatever may be their inclinations, will be interested in the results of experiments so striking as described in these pages, while the specialists will find there extended developments and abundant presentation. As far as regards those who have particularly in view the medical applications, all are convinced to-day that there can be no progress in the application of X-rays except in basing on rational data scientific and precise, that is to say, on profound knowledge, qualitative as well as quantitative, concerning the physical properties of the force utilized. This knowledge can be obtained only by a serious and complete study. A treatise such as the one before us will be, therefore, indispensable.

HENRY LEFFMANN.

HISTORICAL REVIEW OF THE OBJECTS, ORGANIZATION AND ACTIVITIES OF THE CHEMICAL ALLIANCE, INC., DURING THE WORLD WAR, 1917–1919. 8vo., 82 pages.

The data presented in this book have been brought together in the present form at the request of the Historical Bureau of the General Staff, U. S. War Department. The Chemical Alliance was an outgrowth of the Committee on Chemicals of the Advisory Commission of the Council of National Defense, which latter was created under an act of Congress, approved August 29, 1916.

The text gives minutes of the meeting of the Council of National Defense, and the organization of the Chemical Alliance, which it appears, was primarily formed at the request of the Department of Commerce for the handling of foreign pyrites. This was in the latter part of July, 1917. The organization, however, was an alliance of all branches of chemical industry and was active in dealing with all problems of a chemical char-

acter growing out of the conditions of war. These problems had far-reaching relations for labor questions and draft exemptions were involved.

The data given are therefore, quite interesting.

HENRY LEFFMANN.

COKE-OVEN AND BY-PRODUCT CHEMISTRY. By Thomas Biddulph-Smith, F. C. S. Gold medallist, Coke-Oven Managers Association. x-177 pages, index, 62 illustrations and 7 folding plates, 8vo. London, Charles Griffin & Co., Ltd., and Philadelphia, J. B. Lippincott Company, 1921.

The importance of the chemistry and engineering of all processes relating to tar is constantly growing, and it is apparent that all great nations must cultivate a scientific knowledge of these industries. The incidents of the last war have brought home to all thinking persons the many-sided character of such procedures.

The book in hand is a comprehensive account of the chemistry of coke-oven tar and its treatment up to the extraction of the so-called "crudes," which are described in both their commercial forms and pure condition. Processes of analysis are given in detail. The work is very largely illustrated and the descriptions are not confined to the tar alone nor to the hydrocarbons obtained from it, but other by-products are considered.

Beginning with a statement of standard methods for the analysis of the coal, including tests of coking qualities, the subject of the incondensed products of distillation is taken up. Eighteen pages are devoted to this, followed by a brief statement of the analytic method for flue-gases. The testing of the several fractions of the tar distillations then follows. The ammonium sulphate plant is not overlooked.

The work is essentially, as its title indicates, a compact and very useful summary of the principal chemical problems concerning coal-tar.

The numerous illustrations and graphic representations of data on large plates add greatly to the value of the book. A list of elements, atomic weights and symbols and a chapter on the preparation of standard solutions are appended. The atomic weights are those of 1918, but a revised list was published in 1920, probably, however, too late for incorporation in this work.

HENRY LEFFMANN.

THE CHEMICAL EFFECTS OF ALPHA-PARTICLES AND ELECTRONS. By Samuel C. Lind, Ph.D., Physical Chemist, U. S. Bureau of Mines. 8vo, 182 pages, including all parts, 8 illustrations and 22 tables. New York, The Book Department, The Chemical Catalog Company.

This is one of the American Chemical Society's Monograph Series, arrangements for the publication of which were made in 1919 at sessions of the Interallied Conference of Pure and Applied Chemistry. The volume in hand, the second to be issued, treats of an extremely abstruse subject, and one of very recent development, undoubtedly still in its infancy. The phenomena of radio-activity are among the most striking of all phenomena in physics, and have led to great changes in the conception of matter and force. In several respects this book shows original features. The paging includes

the title page and runs to the last page of the index. The old-fashioned Roman paging for the preliminary matter is discarded and can be well spared. Like black-letter, it was a product of the perverse ingenuity of the mediæval writers. Then the title of the publishing company is printed in the new spelling, "catalog," which is also an acceptable change. The general make-up of the book is excellent. Although the Interallied Conference in its earlier meetings did not include Germany among the eligible nations, it is interesting to note that the only four comprehensive works, quoted by title in the preface as specially available for data on the subject of the monograph, are German. It is also worthy of note that the Board of Editors, twelve in number, contains no Philadelphia chemist.

Radio-activity is exhibited by only few elements, those that have the property well marked, radium and thorium, being noted as having the highest atomic weights in the list. It appears, however, that a very rare element, actinium, concerning which little information is at hand, has also this property, and that feeble powers have been discovered in potassium and rubidium, which emit beta rays. Is it possible that our inability to detect such properties in all elements is due to lack of sufficiently delicate methods? It is well-known that the introduction of highly delicate tests in general chemistry has resulted in the detection of traces of substances formerly unsuspected. Most of the metallic elements discovered during the past half-century were found by means of the spectroscope. The combination of this instrument with the sensitive plate has still further widened our information. Perhaps substances may be found that are so sensitive to radio-active emanations that all elements will be taken into the list.

The wealth of material included in the work is too great for brief summary. Glancing over its pages, the chemist feels as if the independence of his science was being threatened, and that it may be at no distant day a mere phase of physics. However, in practical, sanitary and industrial relations the balance and burette will be likely to hold a prominent place, and much interesting work be done and much benefit given the world without close attention to the more abstruse uses of radio-active phenomena. The everyday chemist has seen his importance challenged more than once, and still holds a prominent position. When bacteriology was beginning its spectacular development, Koch said that chemical analysis of water would soon become merely academic, but it is still a feature of all investigations of the applicability of a given supply to household and industrial purposes.

It will be noted from the title that the work does not include the whole field of radio-activity. The preface states that it is the object of the monograph to collect the experimental data and as far as possible to present the collection in such a way as to emphasize the relations between the chemical effects of the material and of the photochemical radiations. The field of photochemistry proper has been presented only to a limited extent, and similarly the subject of radio-activity has been introduced only so far as to make clear the principles and technic involved in the use of such substances as sources of radiations for producing the chemical effects described.

To the majority of chemists, especially teachers, the most interesting chapter will probably be that on Isotopes. The discovery that many of our so-called elements are really composed of closely allied substances has startled most of us perhaps more than the discovery of the X-ray and radio-activity. It is stated that, so far, hydrogen, helium, carbon, nitrogen, oxygen, fluorine, phosphorus and arsenic have given no evidence of compound nature, a fact which accords with the whole-number character of their atomic weights, but boron, silicon, neon, chlorine and bromine have been found to consist of two forms, and krypton and xenon of several. It seems likely that when this problem is worked out the significance of the fractional atomic weights will be known, and Prout's whole-number theory will come into play.

The general introductory informs us that the series of monographs is part of an effort to establish a literature typically American and without primary regard for commercial considerations. Such a purpose will appeal strongly to the majority of chemists in the country, and it is to be hoped that the effort will be successful. Monographs, such as the one before us, are of the greatest use to the mass of profession, because they present in a compact form the results of years of investigation, and summarize literature which is mostly inaccessible to the larger proportion of workers.

HENRY LEFFMANN.

CHEMICAL REACTIONS AND THEIR EQUATIONS. A guide and reference book for students of chemistry. By Ingo W. D. Hackh, Ph.D., A.B., Professor of Biochemistry, College of Physicians and Surgeons of San Francisco. viii-138 pages, including contents and index, 18mo. Philadelphia, P. Blakiston's Son and Company, 1921. $1.25 net.

A summary of the general principles of stating and solving reactions with a great deal of data concerning the stoichiometric problems. Although a small volume, the compactness of the text is such that a very large amount of information has been included. Many small text-books on elementary chemistry have been published, but the work before us is somewhat different in scope and character from the majority of them. It begins, of course, with definitions of the fundamental terms, "atom," "molecule," "ion," and presents the different forms in which the same symbol is used to express the conditions of these three terms just noted. Each chapter is followed by a list of questions. How far this latter plan is beneficial to the student is matter of doubt. If many set questions are provided, students and even teachers may fall into a routine method of using them, instead of allowing the questioning to grow out of the study of the text itself. In connection with the discussion of valence, the negative and positive valencies are indicated by the respective signs placed before the number representing the degree of valency. Thus, hydrogen in the ordinary acids is designated as a monovalent positive and represented by $+1$, while in such compounds as sodium hydride its valency is considered negative and represented by -1. There seems to be a danger of confusion in this method. Most students of elementary chemistry are pursuing the science in association with some departments of mathematics, especially algebra, and such forms of symbols are likely to give trouble. The

usual and better method is, however, followed in the actual equations given, in which the plus and minus signs are duplicated as exponents, using the number of signs equal to the valency of the elements.

The book is practically limited to a study of chemical actions as such, not being an introduction to descriptive or physical chemistry. It is a useful addition to the elementary text-books.

HENRY LEFFMANN.

ÉTUDES ÉLÉMENTAIRES DE MÉTÉOROLOGIE PRATIQUE. By Albert Baldit, president of the Meteorological Commission of the Haute-Loire. 8vo, ix-339 pages and table of contents. Paris, Gauthier-Villars et Cie, 1921. Price, unbound, 15 francs.

Monsieur Baldit was charged with some of the most responsible meteorological duties for the French army during the World War. His interesting book tells in detail what these duties were, and what personnel and instrumental equipments were essential to their proper performance. The chief value of the book therefore is to the military service. But it is also helpful to those who wish to make weather predictions for civil life more comprehensive and exact.

The first 139 pages deal most helpfully with the organization of an efficient meteorological service for military needs. The kinds of stations, their instrumental equipment, their personnel, the kinds of observations to make and the forecasts to issue are all discussed at length. It is even urged that aeroplanes be used for obtaining some of the free air data, and as scouts to actually spy out the weather conditions in all directions from great altitudes.

The second portion of the book, pages 140 to 181, deals briefly with some of the relations between the temperature, pressure, density and altitude of a mass of air; and with the dependence of winds on pressure gradients, latitude, and rotation of the earth.

This is a branch of meteorology in which one often has to chose between mathematical elegance and physical clearness. In this case the former alternative was chosen—a wise enough choice for the properly equipped reader, but disconcerting, perhaps, to those of little or no training in the field of mathematical physics.

The third portion, pages 182 to 335, is devoted to the specific problems of weather forecasting. Several "rules" are given, based on pressure distribution, temperature distribution, winds, clouds, and other sources of information. This section of the book, however, is disappointing; not because of any shortcomings of the author, but because weather forecasting is not an exact science. It is headed that way, for all weather phenomena have their physical causes, but it has a long way yet to go.

All meteorologists can read this book to advantage. The military meteorologist must read it.

There is no index, a really serious blemish which, however, a little time and patience can remove from the next edition.

W. J. HUMPHREYS.

TABLES OF REFRACTIVE INDICES, VOL. II, OILS, FATS AND WAXES. Compiled by R. Kanthack. Edited by J. N. Goldsmith, Ph.D., M. Sc., F.I.C. 295 pages, 8vo. London, Adam Hilger, Ltd. Price £1 5s.

The firm of Adam Hilger, Ltd., has long been favorably known for instruments of precision of highly specialized types, especially in the field of applied optics, and has begun to supplement its manufactures by the publication of reference works upon these topics. The volume before us is a compilation of many thousands of data on the subject of the refractive indices of a class of substances that are of the greatest importance in both industrial and physiologic chemistry. The compiler has searched the literature with great zeal, and his gleanings are set forth in carefully arranged tables. Nearly five hundred references are given covering all important journals and books. Doctor Kanthack has, however, not sought to put on record every datum in regard to a given oil. The determination of refractive index has great practical value. It is more rapidly made than specific gravity and is regarded as a more accurate measurement. The tables contain four columns, showing respectively the temperature (C) at which the determination was made, the values of n_D and B , and an index number which refers to the original sources of the data. The instruments employed in the examinations are the Abbe refractometer and the butyrorefractometer.

A work like this saves the analyst a great deal of time and trouble, for it presents in compact form, easily accessible, a vast amount of data of every day use. The substances are arranged in alphabetical order; the bibliography is numbered consecutively, so that a reference to the source of any datum is, as noted above, easily made.

The mechanical execution of the work is excellent, and it is a valuable addition to the literature of the subject. HENRY LEFFMANN.

LES MOUVEMENTS DES VÉGÉTAUX. DU RÉVEIL ET DU SOMMEIL DES PLANTES. Par René Dutrochet. 121 pages and illustrations, 18mo. Paris, Gauthier-Villars et Cie, 1921.

This is another volume of the series of "Masters of Scientific Thought," which this well-known Paris publishing firm is issuing. The general character of the series has already been set forth in this journal. The question of the consciousness of plants has been answered during the past always in a firm negative, but biologists at the present are, perhaps, not quite so sure on the subject. Of course the first step in the discussion will be to determine what is meant by consciousness, possibly still an unsolvable problem. The distinction between reason and instint has not yet been definitely made, and the distinction between free will and determinism still engages the energies of the theologians and psychologists. The work before us does not enter into these questions, but records a large number of experiments with plant forms, especially the phenomena generally known as the "sleep of plants." Dutrochet's family suffered financially in the French Revolution. His father was an "emigré" and the estates were confiscated. A brief account of the life of the scientist is given in the introduction.

It is interesting to note that though the investigations were made nearly seventy-five years ago, the author's views were much in accord with the more

radical theories of to-day, for he was an inveterate foe of "vitalism," denying that there is any difference between the physiologic and psychologic laws. " Life," he said, "is made up of special chemical and physical phenomena," and he claimed to have made the first step in elucidating these laws, in dicovering the phenomena of endosmose. He was the first to ascertain the condition under which the movement of the sap of plants takes place. The book is written in easy French, and will serve as a convenient exercise to a student studying that language and also interested in biology. HENRY LEFFMANN.

ELEMENTS OF MAP PROJECTION with Applications to Map and Chart Construction. By Charles H. Deetz, Cartographer, and Oscar S. Adams, Geodetic Computer, Special Publication No. 68, U. S. Coast and Geodetic Survey. 163 pages, illustrations, plates, quarto. Washington, Government Printing Office, 1921. Price 50 cents.

This volume is a comprehensive treatise on all the more useful projections presenting them in as simple a form as possible in their general characteristics, mathematical development and actual construction.

Part I covers the subject in general without the employment of any mathematical formulas and serves as a stepping stone to Part II, an arrangement which, it is believed, will best meet the needs of the student and the chart-producing agencies.

In the selection of projections for present-day use in Part II, the authors have limited themselves, with two exceptions, to two classes, *viz.*, projections that are *conformal* and projections that are *equal-area* or *equivalent*. The exceptions are the polyconic gnomenic projections—the former covering a field entirely its own in its general employment for field sheets in any part of the world and in maps of narrow longitudinal extent, the latter in its application and use to navigation.

An interesting feature of the book is given in the frontispiece where a study of a suitable map projection for the United States is presented both by graphical illustration and statistics, including errors of scale, area, and asimuth, in four different projections. It is shown that the projection usually employed for this purpose has a scaling error of as much as 7 per cent. By the use of Albers projection the maximum error of scale can be reduced to 1¼ per cent., and the projection has the additional asset of *equivalence of area*.

Under the subject of "Polyconic Projection" an interesting discussion is given of the merits and defects of the modified polyconic projection as used for the International Map of the World. Another chapter covers the Grid System of Military Mapping as employed in the United States.

The Mercator projection, useful for nautical charts, is presented with detailed and all necessary description, including formulas and tables.

On account of the extensive use of Mercator tables which have not been printed in sufficiently accurate form for forty-eight years, the book should meet a long-felt want. Nearly 15,000 nautical charts are prepared on this system of projection with a probably annual total of over 2,000,000. Under the subject "World Maps" the Mercator projection is again discussed for its usefulness in a continuous conformal mapping of the world, and its impossibilities when extended into the polar regions are explained by the statement that those localities are after all the best places to put the maximum distortion.

For conformal mapping of the world several studies and illustrations are included and among them should be mentioned Guyou's doubly periodic projection of the sphere which, too, has the effect of an interrupted projection.

The problems of world mapping are well outlined in this publication and those projections which have first claim to present-day use are well accounted for at the expense of others which are seldom seen and are more or less geometric trifles.

Due appreciation of the labors of Lambert, Lagrange, and Gauss is shown throughout the book as pioneers in mathematical cartography as well as Gerhard Kramer (Mercator) and the later contributors Germain, Tissot and Herz.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

Report No. 97, General Theory of the Steady Motion of an Airplane, by George De Bothezat. 70 pages, illustrations, diagrams, quarto. Washington, Government Printing Office, 1921.

The writer points out briefly the history of the method proposed for the study of the steady motion of an airplane, which is different from other methods now used. M. Paul Painlevé has shown how convenient the drag-lift curve was for the study of airplane steady motion. His treatment of this subject can be found in "La Techique Aeronautique," No. 1, January 1, 1910. In the author's book "Etude de la Stabilité l'Aeroplane," Paris, 1911, he has added to the drag-lift curve the curve called the "speed curve" which permits a direct checking of the speed of the airplane under all flying conditions. But the speed curve was plotted in the same quadrant as the drag-lift curve. Later, with the progressive development of aeronautical science, and with the continually increasing knowledge concerning engines and propellers, the author added three other quadrants to the original quadrant, and thus was obtained the steady motion chart which is described in detail in this report.

This chart therefore permits one to read directly for a given airplane its horizontal speed at any altitude, its rate of climb at any altitude, its apparent inclination to the horizon at any moment, its ceiling, its propeller thrust, revolutions, efficiency and power absorbed, that is, the complete set of quantities involved in the subject, and to follow the variations of all quantities both for variable altitude and for variable throttle. The chart also permits one to follow the variation of all of the above quantities in flight as a function of the lift coefficient and of the speed.

The author also discusses in this report the interaction of the airplane and propeller through the slipstream and the question of the properties of the engine-propeller system and its dependence upon the properties of the engine considered alone and of the propeller considered alone will be found treated here in the general manner demanded by actual aeronautical engineering practice. There is also a discussion of the question of a standard atmosphere.

The general theory of the steady motion of an airplane is developed, and after the basic equations have been established and the methods to be used described a general survey of the properties of airplane steady motion is given. A detailed discussion of climbing phenomena will be found and the general formulas established for the rate of climb and time of climb, which quantities under the simplest assumptions appear as hyperbolic functions of the ceiling.

PUBLICATIONS RECEIVED.

A Textbook of Organic Chemistry, by Joseph Scudder Chamberlain, Ph. D 959 pages, 12mo. Philadelphia, P. Blakiston's Son and Company, 1921. Price $4.00 net.

Handbook of Standard Details for Engineers, Draftsmen and Students, by Charles E. Hughes. 312 pages, illustrations, 16mo. New York, D. Appleton and Company, 1921. Price $6.00 net.

Traité de Balistique Extérieure par l'Ingénieur général P. Charbonnier. Tome I, Balistique Extérieure Rationnelle. Les théorémes généraux de la balistique. 637 pages, illustrations, 8vo. Paris, Gaston Doin and Gauthier-Villars et Cie., 1921. Price, in paper, 75 francs.

Rayonnement. Principes Scientifiques de l'éclairage, par A. Blanc. 212 pages, illustrations, 16mo. Paris, Armand Colin, 1921. Price, in paper, 5 francs.

Telegraphie et Telephonie Sans Fils, par C. Gutton. 188 pages, illustrations, 16mo. Paris, Armand Colin, 1921. Price, in paper, 5 francs.

Traité de Dynamique, par Jean d'Alembert. 2 vols., illustrations, 16mo. Paris, Gauthier-Villars, 1921.

A Course of Qualitative Chemical Analysis of Organic Substances with Explanatory Notes, by Olin Freeman Tower, Ph. D. Fourth edition, revised. 89 pages, 8vo. Philadelphia, P. Blakiston's Son and Company, 1921. Price $1.50 net.

The Magnetic Mechanical Analysis of Manganese Steel, by Sir Robert Hadfield and Messrs. S. R. Williams and I. S. Bowen. Reprinted from the Proceedings of the Royal Society, A vol. 98. 6 pages, diagrams, 8vo. London, 1920.

National Advisory Committee for Aeronautics. Technical Notes, No. 46, The Theory of the Ideal Windmill, by Wilhelm Hoff. 15 pages, plates, quarto. No. 56, The Development of the German Army Airplanes During the War, by Wilhelm Hoff. 23 pages, plates, quarto. No. 58, Absolute Coefficients and the Graphical Representation of Aerofoil Characteristics, by Max Munk. 11 pages, plates, quarto. Washington, Committee, 1921.

Dyer's Formulas, For Use in Connection with the 1921 Fall Season Shade Card of the Textile Color Card Association of the United States, Incorporated. 25 pages, narrow 8vo. New York, National Aniline and Color Company.

Atomic Weight of Geranium.—John H. Müller of the University of Pennsylvania has determined the atomic weight of geranium by heating a known mass of potassium fluogermanate in a current of hydrogen chloride, and weighing the residual potassium chloride (*Jour. Am. Chem. Soc.*, 1921, xliii, 1085–1095). Seven determinations gave, as an average, an atomic weight of 72.418 for geranium.

J. S. H.

CURRENT TOPICS.

A Novel Magneto-optical Effect. ELIHU THOMSON. (*Science*, June 24, 1921.)—In April, 1921, at the River Works plant of the General Electric Company a curious illumination of the space near an electric welder was noticed as the current was turned on and off. Mr. Malcolm Thomson, the son of the author, examined the phenomenon and found that the luminous effect was spread in the magnetic field of a single loop of the transformer, which was carrying about 7000 amperes. Sunlight from high windows was streaming across the space where the effect occurred. This could be best seen when the observer looked across the magnetic field and also the sunbeam into the shadowed region beneath. The magnetic lines of force were roughly perpendicular both to the beam and to the line of vision. To the person thus directing his eyes the luminous effect manifested itself when the current flowed and disappeared when the current ceased. It was visible four feet from the loop and its intensity varied but little up to two feet from the loop.

The author surmised that the effect might be due to fine particles of iron, or of iron compounds floating in the air, derived from the process of welding. Confirmation of this was got when it was noted that airing the room diminished the conspicuousness of the phenomenon while the bringing up of an iron arc to the vicinity of the loop enhanced it. The fumes from the iron were only fairly visible in the sunlight. At the instant the magnetic field was formed they at once became much more luminous only to become duller as soon as the field disappeared. It was further discovered that a strong direct current in the loop was as effective as the previous alternating current. This shows that the effect is not dependent upon the direction of magnetization. It was early found that the light concerned in this luminous effect was polarized. "The very curious fact was discovered by me that the fumes from the iron arc were composite so far as analysis by the polarizing prism was concerned. The bluish-colored smoke arising gave but little effect, but there was with it a yellowish-gray fume, which was highly luminous in one position of viewing by the prism and invisible when the prism was at right angles to that position. This indicates complete polarization when the field is on, for light diffused from the particles in the yellowish-gray fumes. This is an extraordinary effect, for which no evident explanation suggests itself, for the field lines are not straight but wrap themselves around the coil or loop in curved directions; and the effect is apparently complete even with the fumes rising in the space where the lines are strongly curved."

A microscope slide was made to catch a deposit of the fumes. Under a high power this appeared to consist of rounded particles between .0001 and .0002 mm. in diameter resembling a string of beads with intervals between them. The effect may well be due to these forming lines in the magnetic field. G. F. S.

On the Atomic Weights of Chlorine from Certain Minerals.—MLLE. IRENE CURIE. (*Comptes Rendus*, April 25, 1921.) By the road of analysis through the use of positive rays Aston has shown that chlorine is made up of two isotopes whose atomic weights are respectively 35 and 37. The chlorine which has been used in the determination of the current atomic weight of 35.46 must be a mixture of the two isotopes. If chlorine, derived from various ancient minerals of the earth's crust, be examined will it show the same relative proportion of the two constituents? The general process of comparison was this—the chlorine contained in the mineral was converted into a soluble chloride, and was used to precipitate the silver from the nitrate of silver solution. A soluble chloride of ordinary derivation was made to precipitate the silver from a mass of silver nitrate equal to that previously employed. The weight of the two precipitates of silver nitrates were compared. In one case only was there a difference exceeding experimental error. In two instances no such difference was found. "The result in the cases of apatite and sodalite lead to the thought that in general the atomic weight of the chlorine contained in ancient minerals differs scarcely at all from that of normal chlorine derived from sea water. If this result were generalized, one would be led to conclude that there was a very perfect mixture of the two isotopes before the minerals were formed, or that the two isotopes were made from the beginning in sensibly constant proportions."

G. F. S.

Metric System Adopted in Japan. (*Chem. News*, June 17, 1921, page 286.)—The new Weight and Measure Law as passed by the Diet was formally promulgated recently by the Japanese government, thus rendering Japan one of the metric countries. Simultaneously with the promulgation of the new law, Director Kitsukawa, of the Weight and Measure Office, gave out a statement, saying that even when the first weight and measure law was framed in 1893, Japan was desirous of adopting the metric system, but the nation was not ready to accept it, and the old systems were fully adopted. "Several times since, the wholesale reform of the weight and measure systems has been attempted," the official's statement continues, "but it was quite difficult, before the war, to break with the old systems and adopt the new one to which the nation was but little accustomed. When the World War started, however, the necessity of adopting the metric system was keenly felt, and the Government Bill was readily accepted by the Diet." According to the *Yokohama Chamber of Commerce Journal*, within the five years beginning with the date from which the law takes effect, all public works, government offices, schools, and large factories will be made to adopt the new system, while the general public will be given twenty years' grace.

Bureau of Industrial and Scientific Research and of Inventions. R. LEGENDRE. (*La Nature,* May 28, 1921.)—After a year of the war France mobilized her scientists and her laboratories. At the close of hostilities it became necessary to decide whether this well organized and fruitful service should continue. " In view of the approaching economical awakening that follows all wars, in face of the menace of German industrial activity, seeking with unravaged resources to take prompt revenge for a military defeat by winning an industrial victory, many Frenchmen thought that the time had come to realize otherwise than in mere talk the union of the theoretical with the practical man—an alliance so much desired and urged and the theme of so many jeremiads even before the war." Accordingly Parliament decided to maintain the existing organization and to adapt it to the needs of peace. The director, J. L. Breton, obtained the collaboration of all laboratories, both public and private, of the laboratories of universities and of technical institutions, and of the great centres of independent research, such as the Pasteur Institute, and the Eiffel Laboratory. On the other side he put himself in touch with inventors and assisted them to turn into concrete and useful form their often vague and impractical ideas. The Bureau is now housed at Bellevue, just outside Paris, a town known to many art students of the A. E. F. University. Its methods of procedure arouse memories of similar practices in the United States during the war. The proposals of inventors are first brought before a Main Committee which eliminates utopian ideas and those without interest or practical bearing. The promising projects are referred to competent technical committees, who get into touch with the inventor, inform him of the literature relating to his subject, help him in his researches, assist him in making models, guide him to definite embodiment of his conception and in some cases point out practical applications hitherto not thought of. Every week the chairmen of the committees get together and go over the various suggestions under consideration. Since 1919 more than 500 proposals have been submitted. The Bureau is not merely a passive recipient but takes the initiative in asking for help in the solution of problems pressing on France at the present time, such as the better utilization of fuel, the employment of crude oil for motors and for furnaces, the use of the energy of the sun and of the tides, and the study of the chemistry of soils. Another phase of the work is the assisting of scientists who have a valuable idea but lack material, apparatus or other means to conduct experiments until it is embodied in a practical application. There is a growing number of industrial managers who come to the Bureau with their problems for solution.

An interesting list of practical products of the Bureau is given, including Corne's lighter, which gives a flame under water; the airplane of Gastambide and Levavasseur with variable surface, combining rapid flight with safe landing, and the employment of seaweed in place of oats for horses. On still a different side are to be

noted the information furnished for the protection of blast-furnace workers against gas, methods of ferreting out lesions caused by the injection of substances in order to simulate injuries, moving pictures taken for the study of industrial fatigue, data on building material, studies on helicopters and methods of drying wood.

It is much to be hoped that this very useful Bureau will receive support to a much greater extent from the French government as soon as the financial condition of the country will permit it.

G. F. S.

Dr. Edward Bennett Rosa, chief physicist of the Bureau of Standards, died at his work on May 27, 1921. The son of a Methodist minister, he was somewhat older than most students when he was graduated from Wesleyan University, and his powers were so matured that during his first year at Johns Hopkins he undertook the determination of the ratio existing between the two systems of electrical units and carried it to a successful conclusion. While he was at a later time professor of physics at Wesleyan, he contributed largely to the design and satisfactory operation of the food calorimeter.

In 1910 he was appointed physicist in the Bureau of Standards, and nine years later became chief physicist. His researches deal with the determination of the coulomb and with methods of standardization and measurement, but along with this side of his scientific usefulness went a no less valuable ability to organize and to bring to pass. This quality has been of the highest value in the Bureau.

Those who were fortunate enough to know him well will treasure the memory of the high-minded, deeply religious man even more than that of the leader in physical research. G. F. S.

Acid Sulphates.—JAMES KENDALL and ARTHUR W. DAVIDSON, of Columbia University (*Jour. Am. Chem. Soc.*, 1921, xliii, 979–990), find that barium, calcium, and magnesium form acid sulphates in which one molecule of the neutral sulphate is combined with three molecules of sulphuric acid. Mercurous mercury forms an acid sulphate by union of one molecule of the neutral sulphate with one molecule of sulphuric acid. Silver forms two acid sulphates, in which one molecule of the neutral sulphate is combined with one molecule and two molecules, respectively, of sulphuric acid. Acid sulphates of zinc and ferrous iron exist, but their composition has not been determined. Isolable acid sulphates could not be obtained from the neutral sulphates of aluminum, nickel, lead, ferric iron, copper, and mercuric mercury. The acid sulphates of the alkali metals are more stable and more complex than those just enumerated. Arranging the metals in the order of the electromotive series, formation of acid sulphates is found to be dependent upon the position of a given metal with respect to hydrogen. Extensive for-

mation of acid salts is a characteristic of metals which are much above hydrogen like lithium and potassium, or much below hydrogen like silver. As the zero point is approached from either side, the complex compounds decrease in stability, and finally such compounds cannot be isolated. Solubility relationships follow a similar course. The sulphates of the alkali metals and silver sulphate are extremely soluble in sulphuric acid; those of the metals, which are less pronouncedly positive or negative, are much less soluble; those of the metals, which have electrode potentials near to the zero point, are practically insoluble. J. S. H.

Aero-Photographs of Estates (Harrington's *Photographic Journal*, January 1, 1921).—There recently appeared an advertisement of the sale of an estate, in which features of the property are admirably shown by two aerial photographs taken by the Aerophoto Company. According to the *London Times*, this is the first occasion on which photographs taken from the air have been employed for such a purpose, and emphasis is very properly laid upon the advantages which they possess. The aerial method is able to achieve with certainty, and under any topographical conditions, which has been occasionally possible when a distant view-point on ground at a higher level has permitted. But the cases in which an estate is so situated at the bottom of a basin, on the sides of which the telephotographer may erect his camera at any point of the compass, are few and far between, and even under the most favorable of such conditions one can never expect to show the plan and surroundings of a country mansion in so satisfactory a manner as that which is illustrated in the two aerial photographs to which we are referring. One has only to compare these latter with the eight photographs taken on the ground, which are reproduced on the same page of the *Times*, in order to perceive at a glance the superiority of the aerial method. While that superiority is marked particularly by the showing of the relation of the house to the immediate surrounding country, the architectural design of the building receives at least as adequate a representation as it would in a photograph taken from a relatively near standpoint on the level.

PRESS OF
J. B. LIPPINCOTT COMPANY
PHILADELPHIA